

AQUACULTURE IN SOUTH AFRICA

HISTORY, STATUS AND PROSPECTS



THOMAS HECHT AND PETER J. BRITZ



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Thomas Hecht and Peter J. Britz

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AQUACULTURE IN SOUTH AFRICA: HISTORY, STATUS AND PROSPECTS

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PREFACE

Since the initiation of the National Aquaculture Programme by the Foundation for Research Development in 1984 all branches of aquaculture in South Africa have developed at an unprecedented rate. Despite the increase in the volume of aquaculture research literature, published during this period, little information emerged regarding the development and growth of the industry itself. Clearly, it was necessary to take stock as no comprehensive review had been carried out since Safriel and Bruton published their milestone document entitled: "Aquaculture in South Africa: A Cooperative Research Programme" in 1984. While the Safriel and Bruton document was primarily aimed at prioritising the aquaculture research needs of the time, the focus of this study is on the present status of the industry in South Africa and its needs.

To this end, all major producers in the different branches of aquaculture were interviewed, as well as researchers, administrators, managers and executives of allied industries. By presenting a unified collection of statistics and information the face of the developing industry begins to emerge. Apart from documenting the present status of the industry as a whole, what this document also makes clear is that all branches of aquaculture in South Africa represent emerging technologies requiring research support, venture capital, product and market development and enabling legislation. This study also demonstrates the necessity for a coordinated forum for the promotion of aquaculture, in its entirety, throughout the region.

It is our hope that the present producers will recognise their strength in this unity and use it to their collective and individual ends through producer organisations and in particular through the newly established Aquaculture Association of South Africa.

ABSTRACT

The upsurge in local aquaculture development in the 1980's has been unprecedented and relatively undocumented. The report presents a synthesis of the status of aquaculture in South Africa. Chapter 1 introduces South African aquaculture and places it in context both locally and globally. Chapter 2 traces the history of aquaculture in South Africa. Chapter 3 summarises the regional and geographical characteristics of the South African aquaculture industry. Chapter 4 reviews the present status of commercially viable aquaculture species. An assessment of the state of development of the culture technology, products and markets is presented for each species, as well as the constraints facing producers. Commercial species include trout, ornamental fish and associated organisms, catfish, tilapia, mullet, carp, bass, mussels, oysters, clams, waterblommetjies and crocodiles. Chapter 5 reviews the prospects and constraints for species on the threshold of commercial production. Species in this category include abalone, Atlantic salmon, Spirulina, seaweed, marron, grass carp, brine shrimp, freshwater and marine prawns. Chapter 6 highlights the major constraints facing the industry as a whole and conclusions that may be drawn from the study.

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The realisation of this report is owed primarily to the openness and spirit of cooperation of the more than 80 producers, researchers, administrators, feed manufacturers, wholesalers and other interested persons that were interviewed. To all, the authors express their sincere gratitude and trust that the product meets expectation. A particular thank-you is extended to those, who at short notice, accommodated Peter Britz during his travels. We also thank the two anonymous referees for their valuable comments on the manuscript.

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1 INTRODUCTION

Aquaculture in South Africa during the 1980's has become firmly established as a small but dynamic industry and one that is here to stay. This follows a difficult teething period during the previous two decades, when the potential of aquaculture was realised. Unfortunately due to inexperience and the complete lack of a supporting infrastructure a number of bad decisions and expensive mistakes were made during the 1960's and 1970's. However, during the last five years the true character and potential of aquaculture in South Africa has begun to emerge. This has largely been a consequence of the tenacity of several committed aquaculturalists, the successful initiation of the commercial production of a number of new species, a dedicated research effort and the development of dynamic marketing strategies. Although much has been written about the aquaculture industry in South Africa, inclusive of several attempts to assess its status as a whole, or of some part of it, (Bross 1981, Bruton & Impson 1986, Pott 1979, 1986, 1987, Grosser-Hofer 1982, Duncan-Brown 1978, Safriel & Bruton 1984, van der Bank & Walmsley 1987, Genade & Hirst 1984, Hecht 1984, Myburgh 1986, Uys 1989) the important developments made in the 1980's have not been comprehensively assessed and documented.

The aim of this study was to gather accurate information from producers, researchers, allied industries and administrators on various aspects of the industry and then to define the status and future prospects of the industry. In order to achieve these aims two extended journeys were undertaken to visit and interview as many of the major mariculture and freshwater aquacultural producers as possible. Fifty producers were interviewed personally throughout South Africa and Namibia and another 35 were interviewed over the telephone. The latter group also included researchers, wholesalers, feed manufacturers, administrators etc. The information obtained in this way was supplemented with a thorough review of the literature.

The value of such an undertaking does not only lie in the presentation of production statistics for the various freshwater and marine species but in the hope that the information provided will serve to illustrate the dynamic nature and the self confidence of the aquaculture industry in South Africa today. This in turn is important for financial institutions to provide loan capital for the development of aquaculture projects. In addition we hope that the report illustrates the need for more enabling legislation by the authorities and increased financial support for aquaculture research. It naturally also provides a benchmark upon which to assess the future growth of the industry.

The most illuminating document on aquaculture in South Africa is the study by Bross (1981), who discusses the development of the industry from an economic perspective. His approach was fundamentally correct as aquaculture is afterall a form of aquatic farming for profit. His central thesis was that the failure of aquaculture to develop satisfactorily in the past was partially a result of legal and administrative obstacles on the one hand and as a consequence of inappropriate marketing strategies on the other. It will become clear later in this document that the development of dynamic marketing strategies has contributed greatly towards the present status of the industry in South Africa.

In order to view the development of aquaculture in South Africa in perspective we present a brief summary of the present state of world aquaculture. This is based largely on statistics published by the Aquaculture Development and Coordination Programme of the FAO in 1975, 1981, 1983 and 1985. The importance of these production statistics are firstly to consolidate the present state of the industry, and secondly to demonstrate the significant gains which have been made in the past decade in all sectors of the industry. The importance of these statistics have, on a worldwide basis, also contributed

towards the realisation, by government departments, of the potential of the industry and the need to support it (Nash 1988). The FAO statistics are unfortunately fraught with controversy due the heterogeneous sources from which they are drawn (Chua 1986, Shepherd & Bromage 1988, Nash 1988). Nevertheless, the most current (1985) estimate of world production of finfish, molluscs, crustaceans and seaweed is in the order of 10.59 million metric tons. Of this tonnage finfish contributed 44.5%, molluscs 26.5%, seaweeds 26.2%, crustaceans 2.5% and others 0.3%. Chua (1986) calculated that world aquaculture production increased by 10.5% on a yearly basis between 1972 and 1983 so that the production had more than doubled over this period. The percentage increase between the 1983 and 1985 FAO surveys indicated that finfish and crustacean production increased by 5% and 115% respectively.

The ten most important aquaculture producing countries (those producing more than 200,000 metric tons per annum) are listed in Table 1. Analysis of these data show that the Asian countries are by far the major producers (ca. 88 %) (see Figure 1). The reason for this is simply that aquaculture in Asia

(particularly in China) has been part of the traditional rural economy for over 4000 years (I-Chiu Liao 1988). I-Chiu Liao quite justifiably makes the point that Asia is the cradle of aquaculture. Of the various Asian aquaculture countries Japan and Taiwan probably have the world's most advanced and varied fish farming industries (Shepherd & Bromage 1988). Some 60 species

TABLE 1. The ten most important aquaculture production countries in 1985. Production figures in metric tons. Data obtained from FAO (1987) and I-Chiu Liao (1988).

COUNTRY	TOTAL	FINFISH	CRUSTACEANS	MOLLUSCS	SEaweeds & OTHERS
China	5,202,200	2,392,800	42,700	1,120,000	1,646,700
Japan	1,184,300	283,900	2,200	359,800	538,400
Korea	790,200	3,700	100	369,000	417,400
Philippines	494,400	243,700	29,900	37,900	182,900
U.S.A.	353,200	195,200	29,800	128,000	0
Indonesia	309,900	271,900	38,000	0	0
U.S.S.R.	296,000	296,000	No data	No data	0
Taiwan	231,400	130,200	49,100	42,000	10,100
France	215,800	34,000	200	55,500	0
Vietnam	204,000	191,000	13,000	0	0

of freshwater and marine fishes, 14 crustaceans, 19 mollusc species, 2 reptile, 2 amphibian and 7 species of seaweed are cultured in Japan and Taiwan for human consumption. On a comparative basis the species presently cultured on a commercial scale in South Africa for human consumption include 6 species of finfish, one aquatic macrophyte, one reptile and six species of molluscs (see Table 2). In the six year period since 1984 the number of species cultured for human consumption have, however, more than quadrupled (cf. Safriel & Bruton 1984). The 1984 list of commercial food species consisted of rainbow trout, Pacific oyster and waterblommetjies.

TABLE 2. South African aquaculture species (EX = experimental, E = extensive, SI = semi-intensive, I = intensive, SW = seawater, FW = freshwater, BW = brackishwater, F = food, AT = aquarium trade, A = angling, O = other, * = currently in commercial production for human consumption, ** = currently in commercial production but not for human consumption).

COMMON NAME	SCIENTIFIC NAME	CULTURE STYLE	ENVIRONMENT	USE
FINFISH				
* Rainbow trout	<u>Oncorhynchus mykiss</u>	I	FW, SW	F,A
Brown trout	<u>Salmo trutta</u>	I	FW	A
Salmon	<u>Salmo salar</u>	EX	FW, SW	F
* Catfish	<u>Clarias gariepinus</u>	E,SI,I	FW	F
* Tilapia	<u>Oreochromis mossambicus</u>	E	FW	F,A
Red tilapia	<u>Oreochromis sp.</u>	EX,SI	FW	F
Red breast	<u>Tilapia rendalli</u>	E	FW	F
* Grey mullet	<u>Mugil cephalus</u>	E	FW	F,A
* Carp	<u>Cyprinus carpio</u>	E,SI	FW	F,A
Silver carp	<u>Hypophthalmichthys molitrix</u>	EX	FW	F
* Grass carp	<u>Ctenopharyngodon idella</u>	SI	FW	F
Black carp	<u>Mylopharyngodon piceus</u>	EX	FW	F
Bighead carp	<u>Aristichtys nobilis</u>	EX	FW	F
Galjoen	<u>Coracinus capensis</u>	EX	SW	F
Leervis	<u>Lichia amia</u>	EX	SW	F
**Ornamental	ca. 35 species	I,SI	FW	AT
MOLLUSCS				
* Oysters	<u>Crassostrea gigas</u>	E,SI	SW,BW	F
*	<u>C. margaritacea</u>	E	SW,BW	F
* Mussels	<u>Perna perna</u>	I	SW	F
*	<u>Choromytilus meridionalis</u>	I	SW	F
*	<u>Mytilus galloprovincialis</u>	I	SW	F
* Clams	<u>Macra tra glabrata</u>	EX,SI	SW	F
*	<u>Tapes philippinarum</u>	SI	SW	F
Abalone	<u>Haliotus midae</u>	EX	SW	F
CRUSTACEANS				
Marron	<u>Cherax tenuimanus</u>	EX	FW	F
Prawns	<u>Macrobrachium rosenbergii</u>	EX	FW	F
Brineshrimp	<u>Penaeus sp.</u>	EX	SW	F
	<u>Artemia sp.</u>	EX	SW	O
REPTILES				
* Crocodiles	<u>Crocodylus niloticus</u>	EX,SI	FW	F,O
AQUATIC MACROPHYTES AND ALGAE				
* Waterblommetjie	<u>Aponogeton distachyos</u>	E,SI	FW	F
**Ornamental	<u>Spirulina sp.</u>	EX	BW	O
COELENTERATES	various species	I,SI	FW	AT
**Red bait	<u>Pyura stolonifera</u>	E	SW	O

In comparison to the east, aquaculture in the western world has never been a traditional activity (least of all in South Africa), despite its early beginnings. The ancient Egyptians appeared to have developed the technology for the rearing of several indigenous fish species some 2500 years BC (Eisawry & El

Bolock 1976). The keeping of fish in ponds in Egypt is also mentioned in the Bible (Isaiah chapter 19, verse 10), and the Romans developed a primitive technology for the culture of oysters (Sandifer 1988). Nevertheless modern aquaculture in the west is comparatively young, and can only really said to have developed since the middle of the 18th century when Jacobi developed the technique of stripping and artificially fertilizing trout eggs

GLOBAL AQUACULTURE PRODUCTION CONTRIBUTION OF MAJOR REGIONS

Asia 84.3%

Africa 0.57 %

Europe 8 %

USSR 2.8 %

USA 4.4 %

Figure 1

(Woynarovich and Horvath 1980). Sandifer (1988) correctly points out that aquaculture in the west is a "sunrise" industry with a tremendous amount of vigour, growth potential, an identity crises and the growing pains of any adolescent. In 1987 the prestigious Wall Street Digest identified aquaculture as one of the top ten high tech investments to be made.

Presently aquaculture in the west only contributes some 13 % to the total world production figure. However, in the last 30 years there have been a number of western aquaculture success stories, notably the culture of salmon, red swamp crawfish, channel catfish and shrimps (Sandifer 1988). The most remarkable of these is the farming of Atlantic and Pacific salmon. Already by 1985 fish farming accounted for 5.3% of the world salmon supply and this figure is expected to approach 26% by 1990 (U.S. Department of Commerce 1988). Since 1980 production has doubled every year and it has been predicted that farmed salmon could account for 226,000 tons by 1990. The National Marine Fisheries Service (U.S. Dept. of Commerce 1988 - in Sandifer 1988) further estimates that Norway alone could produce in the region of 100,000 tons by 1990. The principal countries involved are Norway, Scotland (plus various other regions in the UK), Canada and the USA.

The channel catfish industry is largely restricted to the southern states in the USA. In 1970 the production of farm reared catfish was in the region of 2600 tons. It took a further seven years to reach a level of 10,000 tons. The growth of the industry in the eighties has, however, been phenomenal. In 1986 a total of 97,000 tons were produced. The key to this particular success story lay largely in the development of a comprehensive, dynamic and aggressive marketing strategy.

Another US success story is the culture of red swamp crawfish. The industry got off the ground in the early 1960's and by 1987 produced some 54,000 tons (Sandifer 1988). Ecuadorian shrimp farming is a further example of dedication and ultimate success. Since 1978 production has mushroomed from ca. 6000 tons to near 65,000 tons in 1987 (Sandifer 1988).

Turning our attention momentarily to the South African aquaculture scene we predict that the farming of African sharptooth catfish, Clarias gariepinus will similarly show phenomenal growth in the next

decade. Prior to 1987 catfish culture was largely experimental. In 1987 the first 10 tons were produced and the estimated production for 1989 is presently pegged conservatively at 430 tons. During 1989 there has been an unprecedented increase in interest and investment, which has led to a near tenfold increase in total fishpond area since 1987. Coupled with the interest in production there has also been a dynamic thrust into the field of marketing. At this stage we would rather refrain from venturing a guess at the size of the industry five to ten years hence. Similarly the recent progress made in the culture of mussels has been most encouraging.

The relationship between harvest fisheries and aquaculture is also of interest and significance in a discussion on the present state of the industry in the world. The Food and Agricultural Organization of the United Nations (FAO) predicts a likely leveling off of marine fishery landings at around 90 million tons per year. The demand for fish and fish products, however, continues to grow at a rapid rate. It is quite obvious that the shortfall will have to be supplied by aquaculture. Consequently we believe that government assistance in terms of research and development is crucial and that the world aquaculture industry overall bears a heavy responsibility towards the future protein requirements of mankind. In the United States the situation has already been reached that were it not for aquaculture the existing demand for salmon, catfish, shrimp, oysters, mussels and clams could not be met. In South Africa, similar to the rest of the western world, and particularly the USA, the culture of salmonids also supports a booming recreational sport fishery. In fact angler demand for salmonids was the very stimulant for aquaculture in South Africa in the late 19th century. Nash (1988) predicts that aquaculture production will probably approach 22 million tons and account for 25% of total world fishery production by the year 2000. In relation to the total annual landings of the South African marine fishery the contribution made by aquaculture in absolute figures is presently still insignificant. However, of significance is the relative increase in aquaculture production as a percentage of total marine fish landings. In 1983 aquaculture only contributed some 0,093 % to the total tonnage of fish, while by 1988 this proportion had increased threefold to 0,336 %.

The contribution made by Africa to the world total is small (Table 3). In 1985 a total of 61,000 tons were produced in Africa (excluding South Africa), i.e. 0,58% of the world total. The most accurate

production figure for South Africa is the 1988 total (viz. 3059 tons), which is a mere 5,01% of the 1985 African total, or 0,029% of the 1985 world total.

Table 3. World aquaculture production in 1985 (in metric tons)

	Finfish	Crustaceans	Molluscs	Others
Africa	60,600	100	400	0
North America	197,000	33,800	160,800	200
South America	28,500	32,900	1,900	4,900
Asia	3,792,600	198,500	2,120,000	2,795,700
Europe	340,800	300	495,000	4,500
Oceania	1,200	100	20,500	200
USSR	296,000	0	0	0
Totals	4,717,500	265,700	2,798,600	2,805,300
Percentage	44.5	2.5	26.5	26.5
Grand Total	10,587,300 tons			
(Source:	Nash 1988)			

Overall the review will show that the "modern" South African aquaculture industry is still very much in the juvenile stage of development. Nevertheless, it is a robust juvenile and some significant local progress has been made in the fields of culture technology, marketing strategies and practical and scientific innovation. These

developments augur well for the future of the industry. This investigation also shows that aquaculture development, in South Africa, cannot rely simply on the transfer of technology from elsewhere in the world. Central government support for research and development is therefore fundamental for the successful future of the industry.

Unlike in the United States, Europe or the Far East freshwater resources in South Africa are limited (Toerien 1986). This has often been referred to as the major limiting factor to the development and expansion of aquaculture in the country. However, it should be borne in mind that aquaculture is not a net user of water, except that lost through evaporation. It only borrows water, whereafter it is enriched and in most instances better suited for irrigation purposes than before. While we would agree that the availability of suitable water obviously limits the extent to which freshwater aquaculture can grow, it should not inhibit the creativity and initiative of potential producers and scientists. Analogous to the South African situation are the conditions in Israel. Yet the industry in that country is presently one of the world leaders in terms of innovation as well as production levels.

From a mariculture point of view the entrepreneur also has to contend with a number of, at first glance, limiting factors. These are the high energy nature of the South African coastline and the paucity of inlets and bays. Nevertheless, the progress in South African mariculture shows that success is possible. Greater, but judicious, use should however be made of our estuaries. A policy should be developed by the provincial authorities to promote the use of several selected estuaries for mariculture. The area made available in such estuaries could, for example, be calculated on a pro rata basis depending of the surface area of the given estuary.

However, fundamental to the future success of the industry in South Africa is the coordinated amalgamation of the various interest groups, the development of a dynamic and progressive national aquaculture plan, the finding of a statutory home for the industry followed by the promulgation of an Aquaculture Act. The need for a "permanent governmental address" for the industry was recently also identified by the Deputy Minister of Agriculture (van Niekerk 1988). These necessary steps for the rational development of the industry are not unique to South Africa. Similar steps were taken by the industry in most western countries (eg. *inter alia* Denmark, the USA, Canada, the UK, Norway) and also in Taiwan in the last four decades. It was not until the governments of these countries actually recognized aquaculture as a highly productive and dynamic industry, with great potential, that policies were developed and executed and that programmes were initiated to support its growth (cf. Joint Subcommittee on Aquaculture 1983). The necessity for greater coordination within the South African industry and the necessity for an aquaculture development plan has been voiced by producers, scientists, the South African Agricultural Union, the Foundation for Research Development, and more recently also by government (van Niekerk 1988). The earliest calls for a national development policy or plan were made by Champion (1979) and Bross (1981). Bross (*op cit.*) expressed his views on the matter as follows; "That some progress has been achieved despite the existing barriers to progress (eg. historical, legal and administrative, financial, markets and marketing) attests to the growth potential of certain types of aquaculture. Without an explicit aquacultural development policy, which can be quite conservative, progress will be very slow and disappointing. Only the State can usefully evolve such a policy and put it into action". Walmsley & Bruton (1986) provide the basis for such a development plan. Their paper summarizes the potential benefits of aquaculture to South Africa as a whole. It also lists the restrictions and problems facing the industry at the moment and provides guidelines for their solution. In addition, and primarily on the insistence of the South African Agricultural Union and the Council for Scientific and Industrial Research, the Commission for Administration has recently completed an investigation into the specific requirements of the various sectors of the industry (van Niekerk 1988). The need for greater coordination within the industry was also highlighted by the Commission.

Given that aquaculture provides protein for human consumption, job opportunities and revenue it is our view that every effort should be made to hasten these developments, thereby establishing a sound platform for the orderly and less restrictive development of the industry. Such a platform should provide the impetus for the industry to receive the central recognition it deserves and for government to play a more supportive role in its development.

The South African Agricultural Union has for a long time acted as a foster home for freshwater aquaculture in South Africa (L.H.P. Liebenberg, SAAU, pers.comm), while the marine aquaculture

industry and its development has become the responsibility of the Department of Environment Affairs and estuarine aquaculture that of the Provincial Nature Conservancies. However, considering that aquaculture is essentially aquatic farming it is our contention that the Department of Agriculture should be the "statutory home" of the industry, irrespective of whether production takes place in freshwater, marine or estuarine environments. Similar to other commercial activities there would obviously need to be clearly defined channels of communication between several government departments.

In 1988 the Deputy Minister of Agriculture (van Niekerk 1988) expressed an opinion that there is a need for the various producer organizations to organize themselves into an association to promote the national interests of the industry as a whole. It would therefore appear that this is a prerequisite for the finding of a "governmental home" for the industry.

During the past five years various interest groups (*inter alia* the Foundation for Research Development, the National Aquaculture Committee of the South African Agricultural Union, the Departments of Agriculture, Environment Affairs and Fisheries, Water Affairs, Provincial Nature Conservancies and the Commission for Administration and others), have been actively involved with the promotion of aquaculture (Anon. 1989). At the 1988 Aquaculture Symposium held under the auspices of the Foundation for Research Development and the South African Agricultural Union, a proposal for the establishment of an "Aquaculture Association of South Africa" was put forward (Anon. 1989). Membership application forms were distributed to all interested parties by the Foundation. The primary task of the Association would be to represent all producer organisations, as well as other aquaculture interest groups or individuals (inclusive of aquaculturists, scientists, members of allied or support industries and administrators), and to coordinate and consolidate the promotion of aquaculture. Such an Association would also be in a position to play a leading role in formulating an aquaculture development plan for South Africa and to assist in the development of an Aquaculture Act. The Association was founded late in 1989 and will be formally constituted in 1990. We are of the opinion that this body will also be the ideal liaison vehicle to seek and establish a rightful "governmental home" for the industry, from whence its various member organizations and individuals can obtain the necessary central support and encouragement.

It is our fervent wish that this contribution, which sketches the history of aquaculture and provides an assessment of the present status of the industry, will provide the quantitative foundation upon which to proceed with the formulation of an aquaculture development plan. Hopefully, it will also contribute towards the overall promotion of aquaculture in South Africa.

2 THE HISTORY OF AQUACULTURE IN SOUTH AFRICA.

This chapter deals primarily with the history of those species which are presently cultured on a commercial scale in South Africa. However, there are several other important candidate species which stand on the threshold of commercial production, for example prawns (freshwater and marine), abalone, salmon, brine shrimp and others. Developments of their culture will be discussed in Chapter 5.

A. FISH

The origins of fish farming in South Africa can be traced back to the desire of the early European settlers of this land to catch salmonids in the local streams as they did at home. In 1913 Thompson wrote; "The Colonist, especially if of British blood, seems unable to finally settle down in a new land until many of the animals and plants that minister to his pleasure or profit in the homeland have followed him: his horse and dog, his beehives and flocks, his fruits, his fish, and even his oysters - none are as good in his eyes as those that come from his "own country".

Also, in similar vain Harrison (1951) wrote; "Many of our European settlers had been bred to trout angling. They had to leave it behind with other home-ties, and try to put it out of mind; for surely there is no greater pang in all things connected with sport than the last hour on a beloved trout stream and the final abandonment of the cherished rods and tackle before departing abroad to a troutless region. Think of their reactions, when some leisure or other purpose allowed them their first views of those tantalisingly empty streams in the new land".

The prime mover of the initiative in 1865, to introduce fish from abroad was Charles A. Fairbridge. Supported by several prominent citizens of the Cape (Dr. Abercrombie and Messrs. Stein, Hoole, Chase and others), Fairbridge championed the "Bill for encouraging the introduction into the waters of this Colony of fishes not native to such waters". The bill was laid before the Legislative Council and was promulgated as Act No. 10 of 1867. Soon afterwards Fairbridge imported golden carp and dace.

Because of the 1867 Act the way was at last also clear to revive an earlier idea to acclimatise and introduce trout into Colonial waters. These ideas were championed by Griffiths, the Attorney General of the Cape. The idea was also encouraged by the success of acclimatisation work in Australia at the time. The first steps in this direction were taken in 1875 by Campbell Johnson, who brought out a consignment of brown trout ova on board the "s.s. Windsor Castle". It was the intention to hatch the ova, rear the young and to introduce the fish into the Eerste River near Stellenbosch in the Cape, and into the Umgeni and other rivers in Natal. Unfortunately the ova did not survive the sea voyage. Further attempts at the importation of eyed ova was made in 1882 by J.D. Ellis of King Williams Town and by J.C. Parker of Natal in 1881 and 1883.

These earlier failures did not however dampen the enthusiasm of the sport fishermen. At the 1883 International Fisheries Exhibition held in London attention was focused on the possibilities of trout culture, pioneered in Germany by Jacobi since 1767 (Woynarovich and Horvath 1980) and which was being successfully undertaken in Canada, North America and New Zealand. The Exhibition was attended by Lachlan Maclean (an agent of the Donald Currie Steamship Company in Cape Town), who subsequently, acting largely independently, imported 20,000 brown trout ova in 1884. The eggs were

incubated in the woolwashery of the Waverley Mills in Ceres Road (now Wolseley). Of the 20,000 eggs 17,000 hatched successfully. The fate of the fry was however to follow the same path as the earlier importations. All but three died of zinc and oxide poisoning. However the possibilities were clear, which prompted Maclean to urge the Government to take responsibility for the establishment of trout in South African waters. In 1890 Parliament, although skeptical of the initiative, made a provision for another attempt and the first importation of trout ova on behalf of the Government was made in 1892. Three consignments of ova (brown trout and Loch Leven trout) were brought out by Ernest Latour, who had been appointed to conduct the hatchery work. The ova were taken to the hastily adapted and make-do hatchery on the premises of the Anneberg Brewery of Anders Ohlsson in Newlands. Because of water quality problems, the inadequacy of locally manufactured hatching troughs and a delay in the provision of funds for the construction of suitable rearing ponds the exercise was only partially successful. A total of 20,000 fry were stocked into the Breede, Berg, Eerste and Lourens rivers. Once again the necessity for a proper hatchery with an adequate supply of suitable water was apparent. As a consequence of the partial success of the Newlands experiment Government again stepped in and obtained the lease of a site on the farm Jonkershoek, on the Eerste River near Stellenbosch. A well equipped hatchery was built, and rearing and broodstock holding ponds were constructed (Thompson 1913, Harrison 1956) and from 1894 onwards the success of trout production for the stocking of rivers for sport fishermen was assured. Maclean, who can justifiably be considered the pioneer of salmonid culture in South Africa, then surrendered the control of affairs and John L. Scott was appointed as the first caretaker of the Jonkershoek hatchery, which was now under the control of the Department of Agriculture. In 1895 the first stripping and artificial fertilisation of brown trout ova took place at Jonkershoek and in 1896 rainbow trout ova were imported for the first time. However, these were all dead on arrival. The second importation of rainbow trout ova however provided Jonkershoek with its first breeding nucleus (Po 1986) and rainbow trout were produced there from 1899 onwards.

Initiatives to acclimatise and culture trout in the eastern Province were at this time also well under way and the Frontier Acclimatization Society was formed in 1894. The prime mover behind this initiative was J.D. Ellis in King Williams Town. In 1895, the government of the day also provided a grant to aid the establish of a hatchery at a site in the Pirie Forest, which had been secured by the Society. The first ova to be imported were also brown and Loch Leven trout. These suffered the same fate as the earlier importations to the Cape. A more suitable site in the Pirie Forest reserve was later found. The first successfully reared rainbow trout at Pirie were obtained as fry from Jonkershoek in 1899.

In 1890 a hatchery had also been established at Umgeni in Natal to satisfy the demands of the local sport fishermen there, and by 1895 it was well established (Pike 1980). Similarly by the turn of the century a hatchery had also been established in Potchefstroom in the Transvaal where brown and rainbow trout were also being produced successfully.

When the provincial nature conservancies were established they accepted the responsibility of producing and distributing trout and by then also other sport fish, such as large and small mouth black bass and carp. The conservancies also built new hatcheries or took over the existing ones and assumed the task of promoting aquaculture. By that time however the first trout farm had come into existence (Pott 1986).

The first trout farm in South Africa was established in 1945 by R. Charter at Maloney's Eye in the Magaliesberg, Transvaal. Originally this farm obtained eyed ova from Jonkershoek. However from 1955 onwards ova were obtained from the Provincial Fisheries Hatchery in Lydenburg when it started breeding trout.

The Lydenburg Town Council donated a piece of land to the Province in 1947 and in 1948 it was decided to build a hatchery for coldwater fish. The hatching of ova and the rearing of trout fry commenced in 1949. The original stock was imported from England and Switzerland. A year later the first eggs were stripped from mature fish. Until late 1954 all trout produced at the hatchery were stocked into rivers and lakes in the area, whereafter the hatchery then also supplied Mr Charter at Maloney's Eye (du Plessis 1955, Pott 1986).

The second trout farm was developed at Slaaihoek, which from 1954 to the present is run by Mr Eric Brewer. Brewer initially imported ova from America and Britain and obtained some form Lydenburg, but then started to produce his own, thus being independent of provincial hatcheries (Pott 1986). To a great extent this signified the start of commercial trout farming in South Africa.

Since that time the trout industry has come of age and many problems have been overcome. These included first and foremost an inadequate marketing base, which during the mid 1970's threatened the very existence of the industry. The marketing problems were compounded by an inconsistent supply of fresh trout, inadequate quality control and presentation, and import competition. Probably the greatest problem of all, that of a suitable feed, was overcome in 1959 when a feed company started manufacturing a pelleted feed, based on northern hemisphere formulations. The nutritional requirements of trout under elevated temperature conditions in South Africa have now also been established (McEwan 1986). The South African Trout Farmers Association was formed in 1974. This association has largely been responsible for the orderly and prosperous development of all sectors of the industry. As a consequence of increasing production costs the future of the trout industry undoubtedly depends on the further development of innovative, dynamic and aggressive marketing strategies.

More recently we have witnessed the slow but definite phasing out of trout ova and fry production by hatcheries under the jurisdiction of Provincial Nature Conservancies, particularly in the Cape and the Transvaal. This has been brought about largely by an internal reassessment of their terms of reference concerning exotic fish (Hamman 1986, Skelton & Davies 1986), and also by the request of the Trout Farmers Association, who rightly based their objection on free market principles. The De Kuilen Trout Hatchery for example, originally an extension of the provincial Lydenburg hatchery, has now been privatized.

Despite its near similar chronology to trout culture, the farming of carp in South Africa has been a dismal failure. The primary reasons for its failure were the desultory way in which it was undertaken and poor market penetration, because of its local image as a coarse down market product.

The first common carp were brought to South Africa from Germany in 1859. These fish were also first spawned and reared at Jonkershoek, from where they were distributed into rivers and dams throughout the country mainly for angling purposes. An interest in the commercial culture of carp in South Africa only emerged in the late 1940's. The impetus to get the ball rolling came in 1951 with the establishment of the Lowveld Fisheries Research Station near Marble Hall, under the control of the Transvaal Department of Nature Conservation. This station was expressly developed for research in connection with fishfarming (Lombard 1959, Kruger 1973, Bekker *et al.* 1987). Carp of the Aishgrund x Dinkelsbuhl variety, were first imported to South Africa for culture purposes in 1955. The fish were held under quarantine at Marble Hall and were also spawned there for the first time. The robust nature of the beast, its fast growth rate and its suitability for pond culture led to a second importation from Germany, this time funded by the Transvaal Department of Nature Conservation. The aim of the exercise was to use Marble Hall as a demonstration facility for the promotion of carp culture in the province. The controlled culture of carp at Marble Hall succeeded and fingerlings were distributed to farmers throughout southern Africa (Brandt 1978).

In the late sixties and early seventies many overzealous farmers, particularly in the Transvaal, spent vast amounts on the construction of production ponds for carp. In 1973 a Freshwater Fish Cooperative was founded in the Transvaal to promote the culture of carp. To a great extent the enthusiasm for carp farming was also fueled by articles and instruction guides, published in the popular agricultural and aquacultural literature, extolling the lucrative potential of carp farming. Unfortunately the authors of these articles did not take into consideration the existing price structure of the fishing industry in the country at the time. Bross (1981) also points out that the record of carp farming serves as an example of good intentions carried out under inappropriate conditions. This was also realized by the chairman of the Freshwater Fish Cooperative in his annual report for 1977/1978 when he stated that the farmers had to recognize the fact that the species which they wished to farm and sell was an unknown commodity on the South African fish market (Viljoen 1978).

During the period 1975 to 1978 the total production of carp under culture conditions declined from 30,3 to 1,2 metric tons. During the same period trout production increased from 45,8 tons in 1975 to 126,2 tons in 1978 (Anon. 1979). This was a clear indicator to the aquaculture industry of the time that its energies should be concentrated more on the production of high value products than coarse fish for which there was no market. A survey conducted by the Transvaal Department of Nature Conservation in 1985 revealed that carp farming in South Africa had practically ceased to exist in South Africa (Bekker et al. 1987).

The carp debacle had a powerful negative effect on aquaculture development in South Africa, particularly in official agricultural circles (Bross 1981), and in financial circles. The fact that it failed certainly, for a long time, reinforced the idea that aquaculture in South Africa was unworkable. The failure of carp farming was, however, not restricted only to South Africa. In the UK carp farming also failed for exactly the same reasons (Bross 1981).

In 1968 the first grass carp, Ctenopharyngodon idella were introduced into South Africa (Pike 1980). The primary reason for their introduction was for the control of higher aquatic vegetation such as Potamogeton and the water hyacinth, Eichhornia crassipes (H.J. Schoonbee, Rand Afrikaans University, pers. comm.). In 1977 and later in 1979 silver and bighead carp (Hypophthalmichthys molitrix and Aristichthys nobilis) were imported to South Africa, respectively. The black carp (Mylopharyngodon piceus) was soon also imported. These species, as well as other varieties such as the Dor and Dor 70 varieties of Cyprinus carpio, were imported in an attempt to introduce and establish polyculture as a means of utilizing agricultural waste and thereby producing a relatively cheap source of usable protein for human consumption (Prinsloo and Schoonbee 1985, Jackson 1988). The technology for their artificial spawning has been successfully developed (Schoonbee and Prinsloo 1984), under local conditions and some excellent experimental production figures have been achieved, particularly in the Transkei. However, the potential of the Chinese carps as fully fledged commercial aquaculture species in South Africa is circumspect and any potential investor would be well advised to first of all assess the acceptability of the products by the market.

The farming of tilapia in South Africa was also pioneered at Marble Hall in the middle and late 1950's. There have been several, though unsuccessful, attempts at farming the indigenous Mozambique tilapia, (Oreochromis mossambicus) on a dedicated basis in the Transvaal and in Natal. The primary reason for the failure of these attempts can largely be ascribed to the precocious breeding habits of the species, which results in pond overpopulation and subsequent stunting. Because of its wide distribution in southern Africa it has found its way into most commercial fish farms and is harvested and sold primarily as gate sales. The market demand for the species is however high and fish farmers should simply copy the technology developed in Taiwan, Israel and Japan for its intensive and highly successful culture.

The farming of the red hybrid tilapia is a recent innovation and is currently only undertaken on an experimental basis by two research organizations and several fish farmers. However, because of its external appearance, in terms of body colouration and its silver peritoneum, it is our contention that it might well be a promising aquaculture species in South Africa.

One of the most lucrative sectors of the aquaculture industry in South Africa is the production of ornamental fishes for the pet trade. The first record of ornamental fish to have been introduced into South Africa can be traced back to Simon van der Stel who imported goldfish, Carassius auratus to adorn his home at Groot Constantia. Then in 1867 after promulgation of Act No. 10 of that year, Charles Fairbridge imported, amongst other species, some golden carp (Koi). These lived for several years in a pond on his property. His neighbour, Saul Solomon, obtained some of these fish and reared them for many years. He stocked several ponds in the Peninsula including those in the Gardens in Cape Town.

Today, approximately 80 varieties of ornamental fish are produced and marketed in South African (Andrews 1989), however, the dates of first importation of these fish are obscure. Van Zyl (1989) gives

us some clue as to how these fish were established in aquaria in South Africa. From 1964 he exploited the sea trade in aquarium fish, around the Cape, between the Far East and Europe and South America. These were then distributed to pet shops throughout the country. Other dealers from Durban and Port Elizabeth started off in a similar fashion.

Soon afterwards aquarists started to breed and sell fish to the pet traders in all the major centres throughout the country. The industry can truly be said to have been developed by the hobbyists in their backyards. The first dedicated aquarium fish farm, and presently still in existence, was started in the early 1970's by M. Kimbel in Welkom in the Orange Free State.

The current major producer of fish for the aquarium trade is Amatikulu Hatchery (Pty) Ltd. Amatikulu is situated in a rural part of Kwa Zulu. The operation was launched approximately eight years ago on a site which was previously occupied by the aquaculture research station of the Fisheries Development Corporation. The company pioneered the intensive culture of ornamental fish in South Africa and has recently begun a development project involving the launching of six small fish farms owned and operated by local Zulu people. At present Amatikulu annually produces and markets some 1,5 million fish of between 70 and 80 varieties and approximately 20% of their total production is exported to Germany. Presently the primary value of exported fish is in the region of R150,000. With the completion of current expansion programmes at Amatikulu it is estimated that total exports alone will exceed R500 000 in 1990 (Andrews 1989).

The most recent addition to the list of commercially cultured species in South Africa is the sharptooth catfish, Clarias gariepinus. Because of its hardy and omnivorous nature, its high fecundity and suitably fast growth rate (Greenwood 1955, van der Waal 1972, Bruton 1979a, b, c, Bruton and Allanson 1980) the potential of catfish as an aquaculture candidate has been realized for a long time. The first attempts at the experimental culture of the species were undertaken by Douglas Hey, at Jonkershoek, in 1941 and then almost three decades later by van der Waal (1972) at Marble Hall in the Transvaal. The present commercial farming technology for this species is based on over one and a half decades of dedicated research. It is also the first instance of a "homegrown" culture technology. This information is contained in a recently published book, entitled: "The culture of sharptooth catfish, Clarias gariepinus in southern Africa" (Hecht, Uys and Britz 1988). Catfish were first successfully cultured on a commercial scale in southern Africa in 1981 by one of us (TH) and Willem Lublinkhof, on the latter's farm in the Mazabuka district in Zambia. The second catfish farm (Cliff Fisheries) was developed by Roy Kannemeyer in 1985 in Kimberley followed soon afterwards by the establishment of Blyde River Aquaculture by Wynand Uys in the eastern Transvaal Lowveld. In a recent survey Uys (1989) reported that there are now seven producers and that another 10 entrepreneurs were developing catfish farms. Considering that the present producers have linked in with the sophisticated fish marketing and distributional network in South Africa and that their product is directed at the middle to upper end of the consumer market we predict that within two to four years catfish production will surpass that of trout. The successful development of catfish culture in South Africa is a good example of coordinated research and development by research organizations and the private sector.

B. SHELLFISH

Although the culture of trout has an interesting and long history the antiquarian honour in the annals of the history of South African aquaculture belongs to the oyster. The first attempts at culturing oysters was made between 1673 and 1676, a mere 23 years after the arrival of Jan van Riebeek at the Cape of Good Hope in 1650. The first experiments were carried out by the then Governor at the Cape, Isbrand Gosker. The ultimate outcome of these experiments are not known. It appears that the interest in oyster culture in the Cape Peninsula was only revived in the 1870's by Fairbridge (of trout fame), Vigors and Elton, who brought in spat and mature oysters from Simons Bay and Mossel Bay and attempted to grow them in the mouth of the Salt River. These endeavours also did not meet with success. The same ill-success met the endeavours of Dr W.G. Atherstone, of Grahamstown, who in 1882 brought in "thousands" of oysters from Mossel Bay and deposited them in the Kowie estuary (Thompson 1913).

An important event took place in 1888 when an "Act to promote the cultivation of oyster fisheries and the discovery of pearl-bearing oysters" was passed by the Colonial Legislature (Act No. 5 of 1888). The legislation led to a flurry of applications to culture oysters at various localities, amongst others at Gordons Bay, Fish Hoek, at the Steenbras river, in the Swartkops river and the Kowie lagoons at Port Alfred. Except for partial success in the Swartkops estuary, near Port Elizabeth, all other ventures failed. In 1892 the Fisheries Commission included the prospects for oyster farming in the scope of their inquiries, and recommended that an expert should be procured with a view to improving the existing indigenous oyster beds and to introduce the best European varieties. This was made possible by a grant of 250 pounds sterling from the Colonial Parliament in 1893. In the same year E.J. Weatherley, who for many years was employed by the Whitstable Oyster Company, arrived in South Africa with 1000 Whitstable oysters and 1000 French oysters (probably Ostrea edulis). The oysters were laid down in the Swartkops estuary but all eventually succumbed. The following year a further consignment of oysters from Whitstable were imported and these together with some 4000 indigenous rock oysters, obtained from the Port Alfred area, were laid down in beds in equal proportions in the mouth of the Berg river and in Saldanha Bay. Similar to the previous attempt this one proved to be no more successful. The negative results of these attempts at establishing oyster farming in South Africa led to the conclusion, at the time, that the conditions along the South African coast were not suited to oyster farming (Thompson 1913).

It was only in 1948 that interest was again revived in the farming of Crassostrea margaritacea at Knysna and two years later, in 1950, of several European varieties. These attempts were again not altogether successful, but nevertheless led to the establishment of the first commercial oyster farm in South Africa (The Knysna Oyster Company) in 1948. The Fisheries Development Corporation, realizing the potential benefits of shellfish farming, initiated a long term research programme to promote oyster culture at Knysna (Genade and Hirst 1984). Initially the research was geared towards developing the technology for the culture of the indigenous Cape rock oyster, Crassostrea margaritacea. The system developed consisted of collecting seed oysters on abalone shells during the summer months and on-growing these on anchored rafts. Owing to variable settlement rates these early trials were only partially successful. This led to the development of the technology for the artificial propagation of the Cape oyster. However, because of the sensitivity of the larvae and the low average temperatures at Knysna and Langebaan it was decided to abandon the work on this species. Largely as a consequence of the success obtained by the British Whitefish Authority with the culture of the Pacific oyster (Crassostrea gigas) a consignment of these oysters was imported in 1973. The initial tests on this species proved to be very successful and because the product was found to be acceptable on the market the farming of Crassostrea gigas has developed into one of the most successful aquaculture industries in South Africa (Genade and Hirst 1984). Presently there are seven oyster farming companies in South Africa, visibly, two in Saldanha Bay, three in the Knysna lagoon, one in Algoa Bay and one in the Swartkops estuary near Port Elizabeth, as well as two farms in Namibia at Swakopmund and Luderitz. The 1988 production figure was in the order of 299 tons, while in 1989 some 400 tons were produced, which only partly satisfied the local demand for fresh oysters.

The culture of mussels in South Africa is a more recent innovation. The phenomenal growth of this industry can be attributed largely to the direct transfer of the raft and rope culture technology from Spain by researchers of the Fisheries Development Corporation in Saldanha Bay during the early 1980's (Genade and Hirst 1984). These attempts did not meet with much success. However, the technology was subsequently successfully adapted for South African coastal conditions by a private company (Atlas Sea Farms (Pty) Ltd). The first commercial mussel culture operation was established in South Africa in 1984. Presently there are three companies operating in Saldanha Bay, one of which also has a site in Algoa Bay. Three species of mussels are currently being cultured. These are the brown mussel, Perna perna, the black mussel, Choromytilus meridionalis and the Spanish mussel, Mytilus galloprovincialis. The successful culture of clams (Tapes philippinarum) in South Africa was also pioneered by private operators in the early 1980's, by technology transfer and the importation of spat from the United Kingdom. Presently there are two producers of this highly prized commodity, one in South Africa and one in Namibia.

C. REPTILES

The distinctive hide characteristics of the Nile crocodile (*Crocodylus niloticus*) led to its being a sought after species by hunters throughout Africa. Crocodiles have consequently been hunted to near extinction. Fortunately by 1975 more than 80 countries had signed the international CITES treaty (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Because of the high demand for the hides of this species the treaty can to a large extent be regarded as the catalyst for the development of modern day crocodile farming (Marais and Smith 1987). The farming of the Nile crocodile (*Crocodylus niloticus*) in southern Africa is of relatively recent origin. The technology was originally pioneered in Zimbabwe in the early 1960's and then slowly, from approximately 1974 onwards, found its way into South Africa. Because of the long lag period (ca. six to seven years) before a return on investment can be realised most crocodile farms were initially developed as tourist attractions. The first skins exported from South African crocodile farms occurred in 1985. During the period 1976 to the present the number of crocodile farms has increased from two to 25 and the total investment in crocodile farming in South Africa in 1988 was in the order of R25 million. The local industry is still in its embryonic stage but nevertheless shows immense potential (Marais and Smith 1988).

D. HIGHER PLANTS

The harvesting of waterblommetjies or water hawthorn (*Aponogeton distachyos*) for human consumption has been a traditional practice in the western Cape for centuries. The current culture technology was developed by the Faculty of Agriculture at the University of Stellenbosch in collaboration with a private company (Langeberg Cooperative Ltd.) in the early 1980's. Most of the present farmers now produce waterblommetjies on a highly intensive basis in specially prepared and managed ponds. Presently, production levels vary between 5 and 10 tons per hectare per year. Most of the harvest is sold as a cash crop to retailers of fresh produce and the remainder is canned and sold on the local and overseas markets as a high priced commodity.

Another interesting development in the farming of macrophytes is the production of ornamental plants for the aquarium trade. While this form of aquaculture has traditionally been undertaken as a backyard activity along with fish breeding, one producer has been growing plants on a dedicated intensive scale since 1964. More than 30 species of aquatic plants are now being produced.

E. ORGANIZATIONAL STRUCTURE AND RESEARCH.

Several aquaculture producer organizations exist in southern Africa, all of which have or still continue to promote the development of one form of aquaculture or another. The first organization to be formed was the "Freshwater Fish Cooperative" founded in 1973. Unfortunately this organization, which was established to promote the culture of warmwater species and in particular carp, no longer exists. The "Trout Farmers Association" (TFA) was formed in 1974. Since its formation the TFA has played a leading role in the promotion of all sectors of the trout farming industry in the country, and it was largely through the efforts of the TFA that the South African Agricultural Union (SAAU) founded the National Aquaculture Committee in 1982. The aim of the SAAU Committee was to strive for the best socio-economic dispensation for all aquaculture producers in the country. Largely as a consequence of the establishment of the SAAU's Aquaculture Committee the fishfarmers now had a channel of communication to higher authorities within the Departments of Agriculture, Waters Affairs etc.

Because the TFA's members were largely from the Transvaal and Natal the trout farmers in the Western Cape unfortunately formed their own independent organization, "The Western Cape Aquaculture Society", in 1985 to serve the interests of salmoniculture in that region. Recently however (August 1989) the Western Cape trout farmers have joined the TFA. In 1986 the shellfish farmers in Namibia formed the "Mariculture Advisory Committee of Namibia" and in 1988 the catfish farmers formed "The Catfish Growers Association of Southern Africa". The crocodile farmers have also established two producer organizations, "The Transvaal Crocodile Farmers Association" in 1988 and the "Nile Crocodile Farmers Association" in 1989.

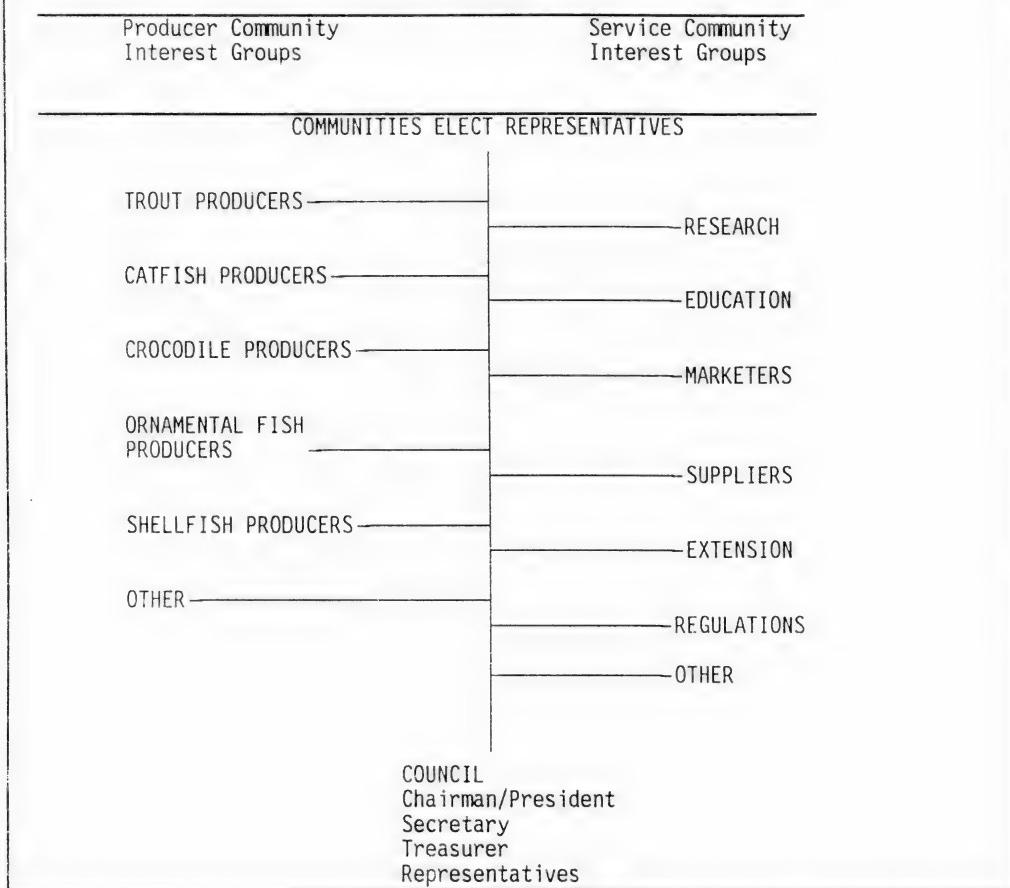
Since the establishment of the provincial nature conservancies until approximately 1980 research support for the freshwater aquaculture industry was principally provided for by the provincial hatcheries at Jonkershoek, Pirie and Amalinda in the Cape, Umgeni and Kamberg in Natal and Lydenburg, Marble Hall and Hartbeespoort in the Transvaal. Later, research was initiated by the Fisheries Development Corporation of South Africa (1955-1985) for mariculture at Knysna, Langebaan, Rhodes University, the Port Elizabeth Museum and at Amatikulu in Natal. It is only since the mid 1970's that other research organizations have shown an interest in supporting the aquaculture industry through research.

The Department of Cooperation and Development (later the Department of Development Aid), realizing the potential of cropping fish from dams and aquaculture in the homelands, established a "National Research Committee for Freshwater Fisheries in Developing Areas". This committee was founded in 1974 and has supported aquaculture research at the Universities in the rural areas since that time. These included the Universities of the North, Zululand, Transkei and Venda.

Apart from the research on the culture of eels, funded by the Fisheries Development Corporation, at Rhodes University during the period 1976 to 1980 very little aquaculture research was undertaken at other Universities. However, in 1981 an Aquaculture Working Group was appointed by the Council for Scientific and Industrial Research. It was the task of this group, under the auspices of the National Programme for Environmental Sciences, to assess the potential of aquaculture in South Africa, to identify the research needs of the industry, to prioritise these needs and to formulate and coordinate an aquaculture research policy. The task of the Working Group was completed and the guidelines for a National Aquaculture Programme were published by Safriel and Bruton in 1984. Research proposals were invited by the CSIR late in 1984 and as from 1985 onwards the research needs of the industry have been addressed, on a priority basis, in a coordinated manner. This development provided not only a welcome boost to the overall aquaculture research momentum in the country but also stimulated the growth of the industry. As will be shown later in this study over 60% of the present aquaculture operations were initiated after 1984. Whether this was solely a consequence of the introduction of the National Aquaculture Programme is obviously open to debate but the development of technology and the dissemination of information and data certainly prompted several entrepreneurs to invest in aquaculture. Several Universities, including Rhodes, Cape Town, Pretoria, Stellenbosch and the Rand Afrikaans University and research institutes such as the JLB Smith Institute of Ichthyology and the National Research Institute for Oceanology of the CSIR at Stellenbosch, the Division of Water Technology of the CSIR in Pretoria and in Natal, now have active and well coordinated aquaculture research programmes. Another important step in the history of South African aquaculture was the establishment, in 1985, of the Fish Diagnostics Unit of the Veterinary Research Institute at Onderstepoort (Bragg 1987).

Because of the progress made during the last four to five years in all sectors of the industry and the increasing number of statutory, scientific and private interest groups it was decided, at the third SAAU / CSIR Aquaculture Symposium in 1988, that the time had arrived for the aquaculture community, in its entirety, to become more effective. A small task group, consisting of representatives of the Trout Farmers Association, South African Agricultural Union, the Foundation for Research Development and the scientific community, investigated the matter and recommended the formation of an "Aquaculture Association of South Africa". In essence the Association would be an umbrella organization for all interested parties to promote and lobby for the development of aquaculture in South Africa at the highest level, to provide a communication vehicle for the dissemination of information, to publish a newsletter on a quarterly basis, to organize workshops and symposia, to improve the interaction between the various sectors of the aquaculture community and to promote research and development. Figure 2 depicts the proposed structure of the Association (Anon. 1989). Membership application forms have been distributed (March 1989) to all interested parties. Such an association would also be the ideal vehicle for the development of an aquaculture policy for South Africa in association with the Department Agriculture, and to promote the promulgation of an Aquaculture Act. By August 1989 the Association received sufficient support from the aquaculture community for it to be formally constituted in 1990.

Figure 2. Proposed structure of the Aquaculture Association of South Africa.



It was proposed that each of the communities would elect a representative to serve on the council, which would thus consist of all interest groups within the community. The council of the Association would deal with global matters affecting the aquaculture industry in South Africa and not with the problems of, for example, the Catfish Growers Association, unless it was requested to do so.

This is an important initiative which, for the sound development of the South African aquaculture industry, should be supported by all interest groups.

3. SOUTH AFRICAN AQUACULTURE AT A GLANCE

Introduction

Despite South Africa's relatively large size and long coast line (approximately 3000 km), a number of geographic and climatic features impose severe restrictions to the development of both freshwater aquaculture and mariculture. Nevertheless, the country offers some exciting prospects. This is witnessed by the successful development of a number of types of aquaculture in the recent past. In this chapter the geographical and regional characteristics of South African aquaculture are outlined, followed by a statistical summary of the status of the industry. Figure 3 illustrates the location of existing commercial aquaculture operations in 1989 and Table 4 and Figures 4a,b and c summarise the production statistics of the various operations.

Geographical Characteristics

Two major factors restrict aquaculture development in the fresh water environment. Firstly, the relative scarcity of fresh water which characterises the South African environment and secondly, the wide seasonal fluctuations in water temperature over most of the interior which precludes the profitable culture of a number of candidate species. For example, over most of the Highveld the winters are too cold for the pond culture of warm water species, while the summers are too warm for the year round culture of salmonids. The culture of cold water species is, therefore, largely restricted to areas of high altitude near the top of catchments where suitably low year round temperatures prevail.

Optimal temperature conditions for warm water species are found in the Transvaal Lowveld and the Natal coastal region. Consequently the majority of catfish, ornamental fish and crocodile farms have been established there. A number of farms which produce warm water species are however situated in sub-optimal regions. In these instances the farmers are forced to increase ambient water temperatures. A relatively recent technical innovation to increase temperature which is finding increasing application in various branches of the industry (particularly among ornamental fish farmers), is the use of plastic covered tunnels. It has been shown that without any additional heating, average year-round water temperatures are ca. 5°C higher than ambient, providing a closed water system is used inside the tunnel (N.P.E. James, JLB Smith Institute, pers. comm.). The use of tunnels thus makes the culture of high value warm water aquatic organisms, such as ornamental fish and catfish, feasible in areas previously considered too cold. Because of the temperature requirements for crocodile farming (ca. 30 - 35 ° C) farmers have to go to greater lengths to increase water temperatures. This is primarily achieved by the use of electrical heaters or heat pumps. The use of heat exchangers are also finding greater application on fish farms, particularly in the catfish industry, during the nursery phase.

The environmental conditions for trout culture in south Africa are marginal. As mentioned earlier ideal sites are largely restricted to high altitude areas with suitable year-round water temperature profiles. Most of the commercial culture operations are centered in the north eastern Transvaal on the Drakensberg escarpment in the Lydenburg, Machadodorp and Belfast areas. In Natal most commercial

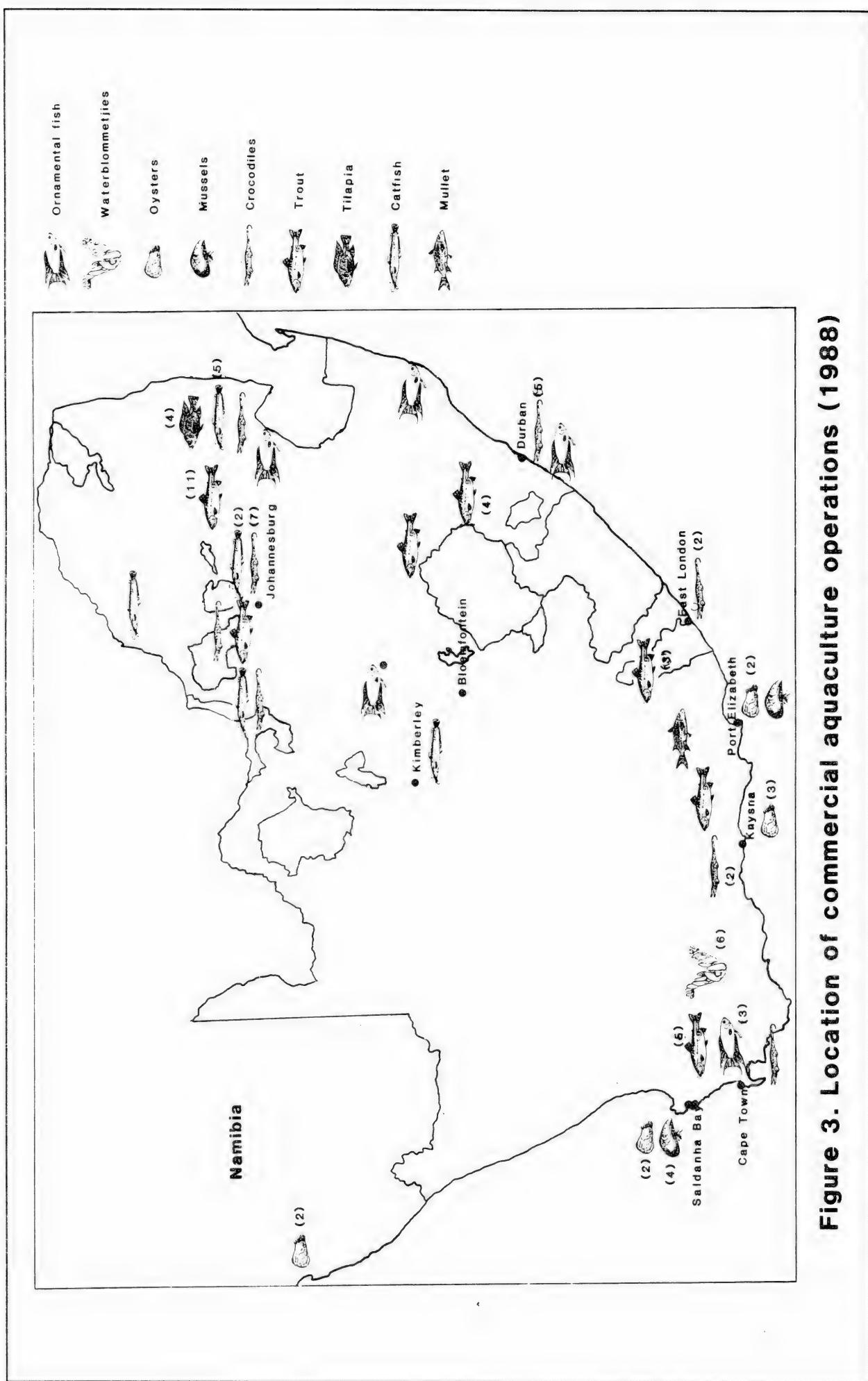
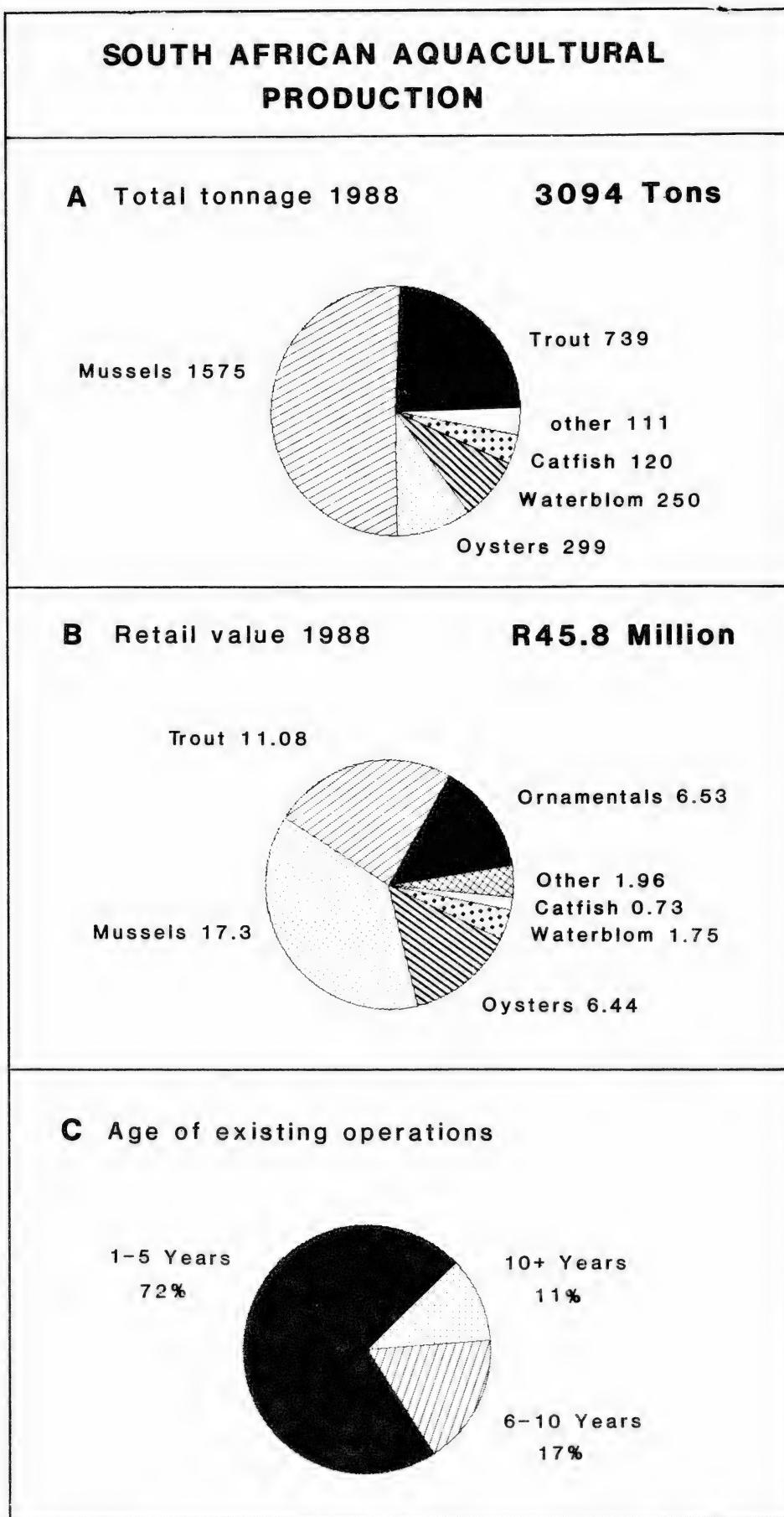


Figure 3. Location of commercial aquaculture operations (1988)

**Figure 4**

production is centered at the foot of the Drakensberg and to a lesser extent in the Midlands. In the Western Cape most production units are based in or below the Hottentots Holland range of mountains. Good waters exist for trout in the eastern and north-eastern Cape region, but the potential of these waters are currently underutilised. Because most of the waters suitable for trout culture emanate either from small streams or springs, in the upper reaches of mountain catchments, the size of South African trout farms are correspondingly small and on average produce less than 100 tons/annum.

The geographic location of waterblommetjie culture operations corresponds to their natural distributional range in the Western Cape. Approximately six farmers now produce waterblommetjies on an intensive basis.

South Africa possesses an exposed, high energy coastline with few suitably protected sites for mariculture. Existing mariculture operations are concentrated in a few sheltered estuaries and bays, viz. Algoa Bay, Saldanha Bay and the

TABLE 1. Production, retail value and number of producers of commercial aquaculture species.

SPECIES	1988			1989 (Projected)		
	Production (Tons)	Retail value (R x 1000)	Number of Producers	Production (Tons)	Retail value (R x 1000)	Number of Producers
FISH						
Ornamental fish (various)	11.50	R6,530	8.00 *	17.00	R9,407	11.00 *
Trout (<i>Parasalmo mykiss</i>)	739.00	R11,085	28.00	1023.00	R15,345	36.00
Catfish (<i>Clarias gariepinus</i>)	120.00	R723	9.00	438.00	R2,628	15.00
Tilapia (<i>Oreochromis mossambicus</i>)	11.00	R38	3.00	33.00	R115	6.00
Carp (<i>Cyprinus carpio</i>)	5.00	R10	2.00	5.00	R10	2.00
Grass carp (<i>Ctenopharyngodon idella</i>)	0.40	R10	1.00	0.40	R10	1.00
Mullet (<i>Mugil cephalus</i>)	20.00	R140	1.00	20.00	R140	1.00
Bass (<i>Micropterus salmoides</i>)	0.68	R14	2.00	1.00	R21	4.00
	<u>907.58</u>	<u>R18,550</u>	<u>54.00</u>	<u>1537.40</u>	<u>R27,676</u>	<u>66.00</u>
SHELLFISH						
Mussels (3 species)	1575.00	R17,325	3.00	1960.00	R21,560	4.00
Oysters (<i>Crassostrea gigas</i>)	299.00	R6,440	9.00	427.05	R9,198	10.00
Clams (<i>Mactra glabrata</i>)	25.00	R288	1.00	30.00	R345	1.00
	<u>1899.00</u>	<u>R24,053</u>	<u>12.00 **</u>	<u>2417.05</u>	<u>R31,103</u>	<u>13.00 **</u>
CROCODILES						
<i>Crocodylus niloticus</i>	37.68 (1884 skins)	R942	25.00	50.00 (2500 skins)	R1,250	25.00
PLANTS						
Waterblommetjies (<i>Aponogeton distachyos</i>)	250.00	R1,750	7.00	300.00	R2,100	7.00
Ornamental plants (various species)	-	R500	1.00	-	R500	1.00
	<u>250.00</u>	<u>R2,250</u>	<u>8</u>	<u>300.00</u>	<u>R2,608</u>	<u>8</u>
TOTALS ALL SPECIES	3094.26	R45,794	99.00	4304.45	R62,637	112.00
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>

* Producers of >50 000 fish per annum.

** Some operations produce both oysters and mussels.

Swartkops and Knysna estuaries in South Africa and at Luderitz and Swakopmund in Namibia.

Atlantic waters are colder but much more productive than the Indian Ocean waters and higher shellfish growth rates are achieved on the west coast. Water quality fluctuations caused by upwelling events on the west coast do, however, lead to occasional problems such as low oxygen concentrations and toxic algal blooms (red tide).

For mariculture to expand in South Africa technologies will have to be developed either for culture in more exposed sites or in onshore facilities using pumped water. However, this requires a considerable measure of ocean engineering research.

Overall status

A summary of the status of aquaculture in South Africa, as reflected by production statistics, is presented in figure 4. A more detailed account of these statistics is given under the species profiles in Chapter 4. Overall, aquaculture has grown rapidly during the 1980's with total production rising from 345 tons in 1980 (Bross 1981) to 3094 tons in 1988, a tenfold increase. Mussels, which have only been cultured for the last five years, accounted for slightly more than half of the total production in 1988. In terms of tonnage trout are second followed by waterblommetjies, oysters and catfish (Figure 4a). In terms of value the order is roughly the same, except that ornamental fish take third place in terms of generated revenue (Figure 4b).

The rapid growth of aquaculture is reflected in the increase in the number of producers in all sectors of the industry over the last decade. Of interest is the fact that over 70% of all the present operations were established within the last five years (Figure 4c).

4. THE STATUS OF COMMERCIALLY PRODUCED SPECIES

A. FISH

RAINBOW TROUT (*Oncorhynchus mykiss*)

Trout farming is the most developed branch of aquaculture in South Africa. Rainbow and brown trout were initially introduced into South Africa for angling purposes in the late 19th century (see Chapter 2). The culture of trout as table fish is, however, a more recent undertaking which started in the late 1940's and early fifties in a fairly informal way. Today, following a rather chequered development, trout production has evolved into a highly intensive operation, based on a sound production, processing and marketing infrastructure.

Production

The historical development of the trout production and processing technology as well as the marketing strategies in South Africa is worth recounting, since it is in many ways a classical model of aquaculture development, and one of the few that exist in Africa. The evolution of the industry parallels experiences in other countries. There are, however, a number of features unique to the South African arena which have determined the nature of production as well as products.

The chronology of development follows a fairly typical sequence, with technological problems initially limiting production which once overcome, were replaced by market factors. Important milestones in the development of trout production were the successful importation of rainbow trout ova in 1896 and the introduction of pelleted dry feeds in 1959. The latter stimulated production to levels where supply started to exceed demand in the mid 1970's (Pott 1986). The seasonal nature of supply, with production peaks occurring from September to November, aggravated the situation even further. Moreover, these peaks occurred during the time of lowest water flow and rising temperature, which meant that farmers either had to reduce stocks drastically or watch them die. This left producers at the mercy of wholesalers who could dictate the price (Pott 1986). Due to these production and marketing problems, many of the smaller producers went out of business during the mid 1970's. The large scale importation of ova from the northern hemisphere from 1979 onwards during the summer months, helped to stabilise production and ensured a relatively constant year round supply of trout to the market. A further development which added impetus to the volume of trout produced was the establishment of specialist trout processing and marketing operations in the late 1970's.

With the establishment of reliable production techniques and a well organised and competitive processing and marketing infrastructure, trout farming during the 1980's has increasingly been viewed as a viable venture. Consequently, the industry is currently in a phase of rapid growth which is illustrated by the fact that over 46 % of the existing trout farms were established within the last five years (Figure 5). In 1988, 739 tons were produced and the projected production for 1989 is 1023 tons (Figure 6). Trout production statistics in the various provinces are presented in Table 5. Due to the

Table 5. Trout production by province.

	1988		1989	
	PRODUCTION	PRODUCERS	PRODUCTION	PRODUCERS (PROJECTED)
TRANSVAAL	400	11	558	13
NATAL	96	4	127	6
CAPE	234	5	343	13
TOTAL	730	21	1028	32

production of 66% of all South African trout farms varies between one and 40 tons, and the production of the remainder lies between 41 and 100 tons per annum (Figure 7). The majority of trout farms are thus small business ventures with fixed assets below R100 000 and are run by an owner/manager. In most instances the venture has been established within an existing farm infrastructure.

AGE OF TROUT FARMS (Years)

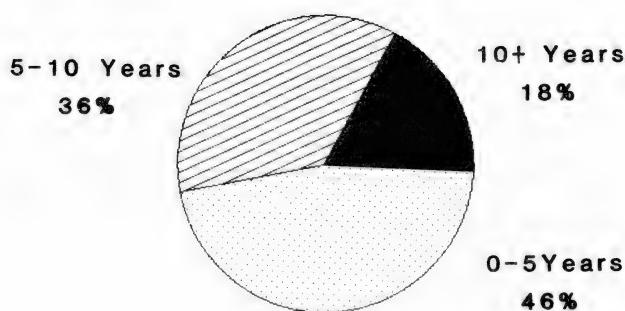


Figure 5

purposes (see below). Two specialist producers of ova now exist and one of them has begun exporting ova in 1989. A lucrative export market is reported to exist for ova during the northern Hemisphere summer. During 1988, the major producers in South Africa produced 14 million eyed ova and approximately 10 million were imported. Projected South African eyed ova production for 1989 is over 20 million.

Constraints

Despite the leading role that the trout industry enjoys in finfish culture in South Africa, the environmental conditions under which trout are produced are marginal. The major factor limiting trout production is the lack of suitable water. Due to the relatively low temperature requirements of trout, production units are typically situated on small streams in the upper reaches of high altitude catchments where clear water and suitable temperatures are found. Farms on these small streams usually experience a seasonal shortage of water (during spring in the Transvaal and Natal and Autumn in the Western Cape). Short periods of high water temperature, which coincide with the times of lowest flow, present

recent increase in the number of producers in the Western Cape, it is expected that this region will produce an increasingly greater percentage of total production. It is expected that this growth rate will be sustained for a number of years, as current operations expand to full production and further producers enter the arena.

A characteristic feature of most South African trout farms is their relatively small output. This is principally dictated by the small size of the high altitude streams upon which most are situated. The production of 66% of all South African trout farms varies between one and 40 tons, and the production of the remainder lies between 41 and 100 tons per annum (Figure 7). The majority of trout farms are thus small business ventures with fixed assets below R100 000 and are run by an owner/manager. In most instances the venture has been established within an existing farm infrastructure.

Besides the production of table fish, important facets of the trout industry are the production of ova and fingerlings for angling

a further environmental constraint in certain areas. To prevent mass-mortalities during these periods, trout farmers are forced to aerate their water, stop feeding and even reduce stocking densities. One producer in the western Cape partially recirculates water to maintain an adequate flow rate during summer, however, this option obviously increases capital outlay and running costs. Interviews with producers revealed that there is a tendency for stocking rates to be too high during periods of low flow and high temperature, resulting in stress, reduced growth rates, disease and mortalities. On trout farms where stocking densities are carefully maintained within the limits of the available water supply, minimal disease problems and low

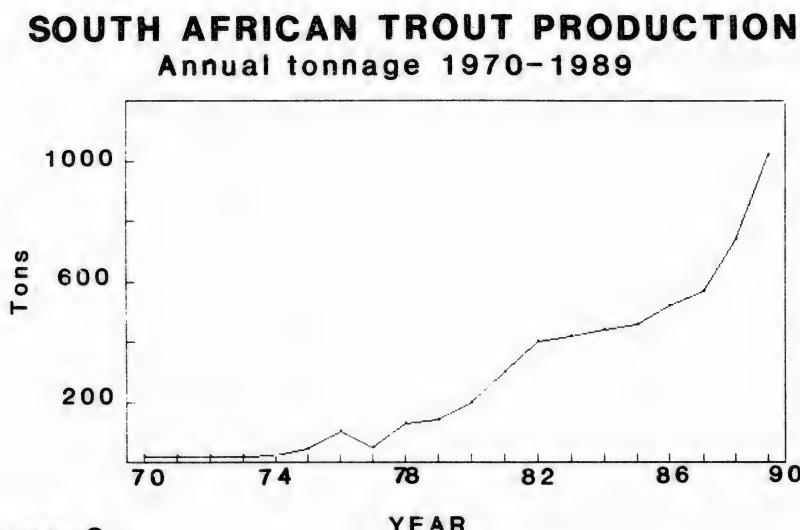


Figure 6

mortalities are experienced. Average stocking densities range between 15 and 20 kg per cubic meter of water, although some farmers report stocking densities as high as 40 kg's per cubic meter.

Flash-floods, are characteristic of streams in mountain catchments and present a further environmental problem. Floods can affect trout farms in two ways; (a) rapid deterioration in water quality with an associated increase in sediment load and, (b) the partial or complete destruction of the physical infrastructure. Several trout farms in South Africa are situated on sites which are prone to flooding. This highlights the importance of site selection during the initial planning phase.

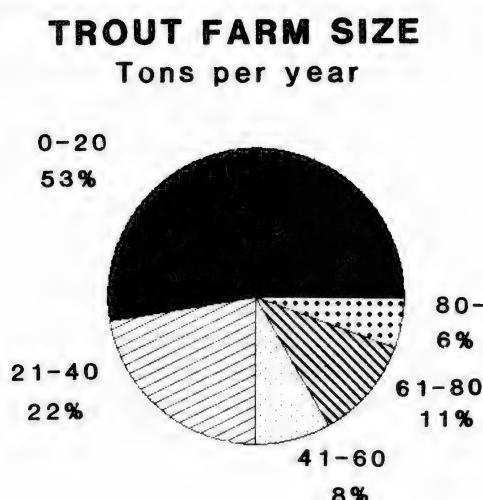


Figure 7

was an attractive option due to the comparatively low initial capital outlay and the prospect of increased production. While good yields have been achieved, serious water quality problems have developed at a number of sites which detrimentally affect production. Algal blooms, caused by an accumulation of nutrients, is the most serious problem ultimately resulting in considerable stock losses.

During the mid-eighties, a number of trout farmers in the Transvaal and in Qwa-Qwa invested in cage-culture facilities, which in many ways

These water quality problems have developed because the man-made lakes in which this form of culture is practiced are relatively small with low flushing rates. There is currently a move away from cages in the Transvaal to conventional stream based production units. A number of producers in Natal and the Western Cape are, however, busy developing cage culture units in relatively small irrigation dams which have high flushing rates.

The single biggest constraint facing trout producers is that of feeds. Recent increases in feed costs, mainly as a consequence of the global increase in the price of fish meal, have alarmed producers who have no control over feed production and supply. For example, during the first seven months of 1989, the price of trout feeds increased by over 20%. The increase in the cost of trout feeds is illustrated in Figure 8. Feed costs currently make up approximately 66% of total production costs. The cost of producing trout is therefore very sensitive to increases in the price of feed. The major ingredient of trout feeds is fish meal which may comprise between 35% and 65% of the total composition. The nominal price of fish meal increased by 30% from 1988 to 1989 and due to its short supply, more increases in the price of fish meal and hence trout feeds are expected. Farmers are concerned that if feed prices continue to increase at their present rate, their product might price itself out of the market. Other prob-

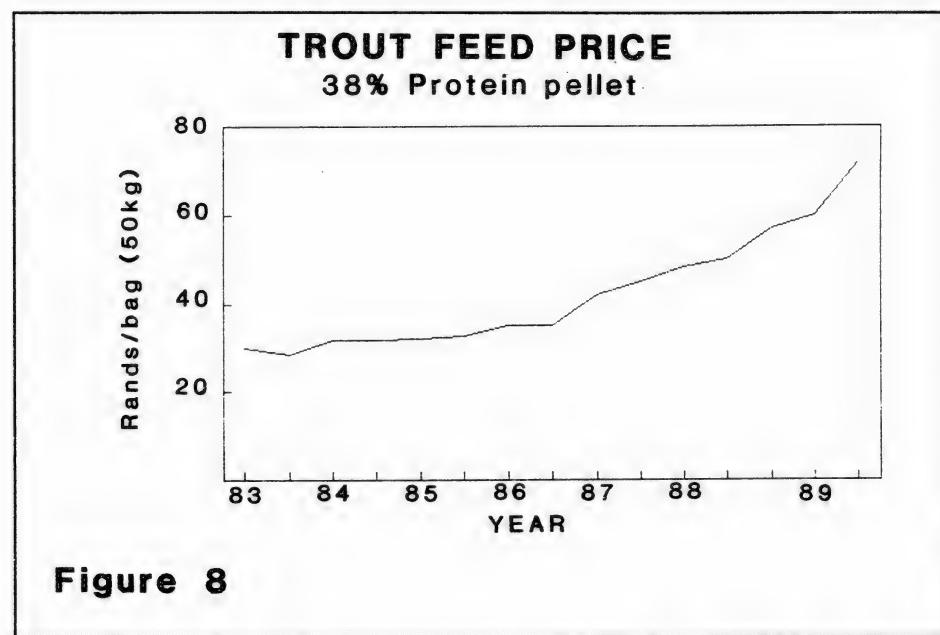


Figure 8

lems associated with feeds relate to its quality, particularly that of starter feeds and poor service by certain suppliers.

There is no simple solution to the problem of high feed costs. As long as fish meal remains a major component of the feed, prices will continue to rise. Improvements are, however, possible with respect to the quality and range of feeds available and the feeding practices on the farms. Crumbles for small fish are currently produced by crushing larger pellets produced by steam pelleting. This practice however produces an undesirably high percentage of fines. The use of the extrusion method of pellet production would eliminate the fines problem and result in a higher quality, harder pellet. Some farmers reported that they feed a single grade of food (38% protein) to all their fish regardless of size and water temperature. Such practices are obviously undesirable as the protein requirement of fry is higher than that contained in the pellet, resulting in poor growth during the fry stage.

The recommendations of McEwan (1986, 1987, 1988) regarding trout feeds under South African conditions provide a number of options for improving the quality of feeds and reducing costs. McEwan demonstrated that the energetic requirements of trout are significantly different in summer and winter. He showed that the formulation of separate feeds appropriate to summer and winter conditions respectively, resulted in better growth rates and potentially lower feed production costs. Unfortunately, very few of McEwan's recommendations have been implemented by the industry. This is largely due to the small demand for trout feed which does not justify the large feed producing companies to invest in specialised equipment or to diversify their product range. However, McEwan proposes that the trout

industry is now large enough to support a specialist feed manufacturing plant (1490 tons of feed were used by the industry in 1988) and makes suggestions regarding the structure of such a facility. If these desired improvements are to occur, trout producers themselves would have to take the initiative.

Processing and Marketing

With the increase in trout production during the 1970's, it became apparent that the existing informal channels used for marketing the product were inadequate. Adverse market related factors, such as a periodic over- or undersupply, an inadequate marketing base, inadequate quality control and presentation, and competition from imports played havoc with the price of trout and a number of enterprises went out of business (Pott 1986). To overcome these problems, a number of specialist trout processing and marketing operations were established, which effectively eliminated these market related problems and substantially improved the image of the industry. The current upswing in trout production is seen as a direct consequence of the establishment of effective processing and marketing structures.

Table 6. South African trout products.

Whole fish
Deboned whole fish
Filletted
Whole with vegetable stuffing
Smoked whole
Smoked deboned
Smoked fillets
Smoked thin slices (Salmon style)
Pates
Terrines

Before the establishment of a specialist processing and marketing infrastructure, trout were sold fresh mainly to the restaurant and hotel trade. However, since the establishment of processing plants, trout products diversified considerably, mostly into the "value added" line of products to the upper end of the food market (Table 6). Product quality is extremely high and processing plants conform to, and even exceed, SABS specifications. For trout to be sold in supermarkets and chain stores, presentation is extremely important. The fish are therefore individually packed in appealing vacuum packs or

printed boxes. In line with the current trend towards high quality convenience products in the food industry, most trout products are designed to minimise preparation time and are presented as pan, oven or microwave ready. The bulk of table trout are harvested at 300-350 grams, a size which is suitable for processing into a single meal portion. Some newly established producers are rearing trout to approximately one kilogram as a salmon replacement. These fish are smoked, thinly sliced and then vacuum packed in the style of smoked salmon. Producers obtain between R7.00 and R9.00 per kilogram for small trout (200-500g) and from R9.00 to R11.00 per kg for larger fish.

The high demand for trout in the very competitive South African table fish market is a reflection of the fairly unique nature, and high quality of these products. The volume of trout produced is obviously very small in comparison to that of the trawl fishery (eg. hake, kingklip). However, due to a lack of diversity in sea fish products (although this is currently changing rapidly), specialist trout products have very successfully found a niche in the market. The target market consists of upper income group consumers who are not particularly price sensitive. Retail prices for trout products range from R18.00 per kg for fresh whole trout (vacuum packed or printed box) to R65.00 per kg for smoked fillets. The retail value of trout products sold in 1988 is conservatively estimated to be R11 million. As mentioned above, a similar trend towards diversification and value added products has also recently developed in the sea fish market (eg. vacuum packed smoked or peppered mackerel, snoek braai packs etc.). This development might be regarded as competition, but owing to the strong image of trout as a traditional delicacy and the sophisticated nature of the various product lines, it would appear that the trout industry will continue to enjoy a high demand for its products.

At the 1989 annual general meeting of the Trout Farmers Association it was pointed out that the present processing plants are operating at maximum capacity. Considering the projected increase in

trout production it was predicted that unless more processing facilities are established many of the new trout farmers would find it difficult to market their products in the future.

Trout fishing

An increasingly important facet of trout farming is the production of live fish for the stocking of angling waters. This role was traditionally fulfilled by the provincial administration hatcheries (Jonkershoek, Pirie, Lydenburg, De Kuilen, Kamberg). However, over the last few years trout production has been phased out by these organisations (see Chapter 2). Commercial producers are now almost solely responsible for the supply of live trout to, what may now justifiably be termed, the trout angling industry.

Trout angling waters, which have traditionally been stocked and maintained through angling clubs, associations and syndicates are increasingly being developed as private commercial ventures. The most common type of operation is the syndication of angling waters by the landowner. Other types of profit making angling organisations include "put and take" fishing ventures (which are becoming popular near cities), timesharing of property on angling waters, hotel-type fishing lodges and dayfishing. Commercially organised trout angling is at its most sophisticated in the eastern Transvaal. This area is easily accessible from the Reef area for weekend fishing. In the Lydenburg / Dullstroom / Machadodorp area more than 50 trout angling syndicates and other ventures now exist.

Producer Associations

Trout Farmers Association of South Africa. Whereas in the past this body catered primarily for the needs of the trout farmers in the Transvaal and in Natal, the producers in the western Cape have now also joined the association.

Trout Research

1. Department of Genetics, Stellenbosch University,
2. Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown.
3. Division of Water Technology, CSIR, Pretoria.
4. Kamberg Hatchery, Natal Parks Board.
5. Research Unit for Fish Biology, Rand Afrikaans University, Johannesburg.

Veterinary Services

1. Fish Disease Unit, Veterinary Research Institute, Onderstepoort.
2. Lydenburg Veterinary Clinic, Lydenburg.

ORNAMENTAL FISH AND ASSOCIATED ORGANISMS

The culture of ornamental fish and aquatic plants for commercial gain has been practiced in South Africa for many years by hobbyists and backyard entrepreneurs. The recent establishment of a number of large scale ornamental fish farms is rapidly transforming the traditionally informal image of local ornamental fish breeding, into one of a highly organised and profitable industry.

Production

Although a few individual ornamental fish breeders have been making a living out of fish breeding for a number of years, the bulk of ornamental fish have traditionally been imported into South Africa. In 1985 ornamental fish wholesalers reported that approximately 90% of freshwater ornamental fish sold in South Africa were imported (Bruton and Impson 1985). Interviews conducted for the present survey revealed that this figure has now decreased to approximately 60%. This directly reflects the upsurge in the local production of ornamental fish. The approximate production of the larger ornamental fish breeders in South Africa is illustrated in Figure 9. This figure excludes production by hobbyists, which constitutes a significant but unpredictable contribution to annual production. The estimated retail value of fish sold by the major producers in 1988 was R6.4 million. Comparison of these figures with the estimated retail value of imported ornamental fish for 1987 of R7.6 million (Andrews 1989) confirms that the proportion of imported fish is now in the region of 60%.

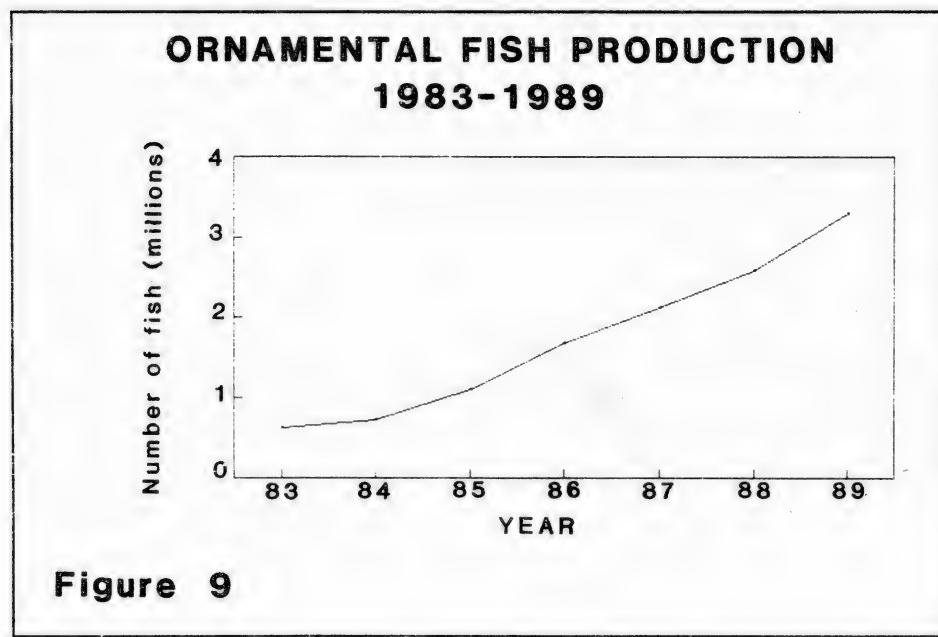


Figure 9

imposed 60% surcharge on imported fish. A recent innovation is the export of fish which has been initiated by Amatikulu Hatchery in Natal. Approximately 10% of local production is currently being exported. Local ornamental fish production is therefore an important industry both with respect to import replacement and foreign exchange earnings.

The present survey has revealed that seven breeders are each producing over 50 000 fish per year and the largest farm produces ca. 1.5 million fish per annum. Due to the variety of species produced (over 60 in South Africa) specialist knowledge of the biology and environmental requirements of the various fish species is required. Most producers breed a wide variety of species, however, one major producer and a number of smaller ones have very successfully specialised into the culture of goldfish. Fish quality is of paramount importance in the ornamental fish trade and well graded, disease free fish with attractive markings fetch premium prices and guarantee continued sales. Ornamental fish breeding is a labour intensive undertaking and a well organised system of production management is required. For example, Amatikulu Hatchery currently employs a labour force of about 25 workers.

Constraints

Production problems reported by producers varied considerably. However, common themes were problems related to management and system design, water quality and disease. No texts or other information services exist for the large scale culture of the various species. The development of commercial rearing facilities has therefore been a trial and error affair. The most successful producers are those who have applied scientific principles of intensive aquaculture and production management to ornamental fish breeding. It is regrettable that, despite offers from various producers, particularly from Amatikulu, for the use of their facilities for research purposes this has not occurred (Myburgh 1986, Andrews 1989). To a great extent this is a clear indication of the shortage of suitably qualified manpower.

Existing production systems range from extensive pond production to intensive indoor culture in which water quality and other environmental factors are carefully monitored and regulated. Wide use is made of plastic tunnels for the rearing of ornamental fish. Extensive systems consist of earthen ponds containing broodstock from which offspring are continually cropped. Such systems are, however, prone to high predation rates, mainly by the platanna Xenopus laevis and various birds, but this can be overcome.

Due to the intensive nature of ornamental fish production, an ever present threat is that of disease. However, the severity and frequency of outbreaks are largely a function of the management efficiency. Well managed production systems are designed to minimise disease risks and facilitate the early identification and treatment of any pathogen. A related factor which detrimentally affects the quality of fish and promotes disease is that of handling stress. This is a very real problem in the harvest and transport of fish and one deserving of research input.

A problem mentioned by a number of producers was the unavailability of a suitable feed for the large scale production of aquarium fish. Flake type feeds imported for the hobbyist are extremely expensive and not suited to intensive culture due to their instability which results in wastage and poor water quality. A need exists for a realistically priced small pellet or crumble which is more stable in water. Amatikulu Hatchery has now, however, taken the first steps in setting up their own food manufacturing plant.

All ornamental fish sold on the South African market are exotic and their status has generated much controversy with regard to conservation policies on non-indigenous species. In 1988, the trade in a large number of exotic ornamental fish was banned which caused great consternation in the industry. All producers agree that some form of control over alien fish is necessary to prevent populations being established in South African river systems. Members of the ornamental fish trade attest the goodwill of officials who regulate importations, however, all felt that the banning of certain species had been somewhat arbitrary and expressed a wish that a more rational basis for the regulation of the trade in exotic fish be established (Van Zyl 1989). The authorities, however, themselves admit to a lack of suitably trained personnel with an adequate knowledge of the various species. Interviews with members of the trade revealed that much confusion existed as to the status of a number of species and the procedure by which they were classified as being either desirable or undesirable. Given the rapid growth of the trade it is imperative that clear guidelines for the regulation of these species be established. This obviously requires cooperation and communication between members of the trade and conservation authorities. A positive move in this direction was the organisation of a symposium on exotic fish by the JLB Smith Institute in 1988 which was attended by members of the trade and conservation authorities (see De Moor and Bruton, 1989). While such events provide a useful forum to define problem areas and air views, structures are required to facilitate ongoing communication, policy making and education. It is seen as essential that the relevant conservation authorities do not act autonomously but make policies on exotic fish in consultation with the industry. To this end the "Liaison Committee on the Importation of Tropical and Exotic Fish for Aquarium Purposes" has been convened by the Department of Agricultural Economics and Marketing to develop appropriate policies

and structures in association with the South African Pet Traders Association. The Pet Traders Association was established in 1988 to represent the collective interests of the trade and promote professionalism within it.

Marketing

A well established wholesale and retail trade exists for ornamental fish. In contrast to the producers of table fish, all producers report that they have no problems marketing their fish and that demand and prices are good. A periodic oversupply of certain species does occur due to "dumping" by hobbyists, however, this is regarded as a minor problem. Andrews (1989) reports that a lucrative export market exists for ornamental fish because the traditional suppliers of farmed ornamental fish are presently experiencing serious difficulties due to industrial pollution and the increasing demand for farm land for industrial and residential development.

ASSOCIATED ORGANISMS

LIVE FEED ORGANISMS

The production of live organisms as feed for ornamental fish is being practiced by a single producer near Vereeniging. Bloodworm (Chironomid spp.) and Daphnia are reared intensively and supplied to the aquarium trade in Johannesburg.

Production

These organisms are produced in plastic pools and harvested on an ongoing basis. Emphasis is placed on the maintenance of pure cultures. Appropriate nutrients are added to maintain Daphnia cultures and the technology for bloodworm culture is being preserved as proprietary knowledge.

Markets

Small quantities of these organisms are packed in oxygenated plastic bags and distributed to dealers. It is reported that they remain alive under these conditions for at least a week if kept refrigerated. Daphnia and bloodworm are also supplied in a frozen form. Despite some competition from imports the aquarist demand for the local products is reported to be good, primarily due to the high quality (ie. no contamination by other organisms).

ORNAMENTAL PLANTS

Ornamental plants form an important compliment to the ornamental fish trade. Only one dedicated producer of ornamental plants is known to exist in South Africa, although many fish breeders and hobbyists produce ornamental aquatic plants as a sideline.

Production

Intensive techniques for the culture of over 30 varieties of aquatic plants have been pioneered over the last 25 years by a producer in Cape Town (Mr E Binnedel, Aquafarms (Pty) Ltd.). Most plants are reared under plastic tunnels erected over the ponds. Species cultured include different varieties of Valisneria, Aponogeton, Accorus and Amazon swords (Perniculatus spp.).

Markets

Due to the well organised nature of the aquarium trade, a well established market exists for ornamental plants. The value of ornamental plants produced locally is not known, however, it probably does not exceed R0.5 million retail.

AFRICAN SHARPTOOOTH CATFISH (*Clarias gariepinus*)

The commercial culture of African catfish in South Africa is a recent innovation (ca. 1986) which has over the last few years generated a great deal of interest. The sharptooth catfish, also known as "Barbel" or "barber" is an indigenous, warmwater species for which the production technology has largely been developed by local research institutions and producers. Although catfish production, processing and marketing are still fairly rudimentary, the prospects for development within this branch of aquaculture are enormous.

Production

Catfish culture technology is currently in the transition phase between research and commercial production. Reliable techniques for fingerling production, feed manufacture and growout have been developed by the research community on an experimental scale, and commercial culturists are now developing cost effective systems for the large scale culture of catfish.

The species possesses a number of unique physiological attributes which make highly intensive culture possible at sites with a relatively small water supply. Their most unique characteristic is their ability to breath air which facilitates very high stocking densities. Furthermore, once catfish are past the fingerling stage they are extremely hardy, displaying minimal stress after handling and possessing a wide tolerance of most environmental parameters. Local catfish farmers currently achieve yields ranging from 10 to 60 tons/ha/year. These figures stand in stark contrast to the American channel catfish industry, where maximum yields of 7 tons/ha are achieved, under conditions of mechanical aeration (Wellborn and Tucker 1985). A flow rate of only 2 to 6 l/sec/ha is recommended to produce ca. 40 tons of catfish/ha/year (Scholtz and Uys 1988). This is equivalent to 18- 46 m³/hr for every 100 tons of catfish produced, a figure which is two orders of magnitude lower than the European recommended requirement for trout of 3600 m³/hr/100tons (Shepherd and Bromage 1988).

Most catfish farms are situated in the Transvaal Lowveld and draw water from irrigation canals, although a very successful operation also exists in the northern Cape, near Kimberley. Operators in the Lowveld employ a one year production cycle and fish are harvested at a size of 800 - 1000 grams. Fingerlings are produced continuously throughout the summer and stocking is structured so as to produce a continuous year round production of market sized fish. At present, only the larger catfish farms possess hatcheries which supply both their own needs and those of smaller producers. During the 1988/9 breeding season, fingerlings (3-5 cm total length) were sold for 10c each.

The nutritional requirements of catfish are well known and a feed has been developed which satisfies the nutritional requirements of the species (Uys 1990). This was a major step that facilitated the establishment of its commercial culture. Catfish feeds are presently manufactured by one producer, one feed manufacturer and a number of agricultural cooperatives. Catfish have fairly general nutritional requirements and are able to digest a wide range of foodstuffs. This facilitates the inclusion of a number of unconventional feed ingredients which reduces the dependence on fish meal. Consequently, the production cost of catfish feeds is substantially lower than that of trout feeds.

The growth of the fledgling catfish industry has been impressive. The first commercial production of catfish was achieved in 1987 when 10 tons were produced by Mr R. Kannemeyer of Kimberley. This increased to 137 tons in 1988 and the projected production for 1989 is 420 tons. The number of active producers has grown correspondingly (Figure 10), increasing from one in 1986 to 15 in 1989. A survey conducted among existing catfish producers (Uys 1989) revealed that they collectively aim to produce 1314 tons once their operations are in full production. By April 1989, 194 catfish production ponds were in existence covering 51 hectares and it is expected that by the end of 1989, 360 ponds will be in existence covering 68.4 ha. The average pond size is 0.16 ha. A Catfish Growers Association of southern Africa was established in 1988. Presently it boasts 82 members, which makes it the largest aquaculture producer association in the country. The overwhelming interest in catfish culture and its rapid establishment as a commercial enterprise are largely a consequence of state funded research

(through the FRD's National Aquaculture Programme). This programme has facilitated the development of the culture technology and the provision of highly skilled manpower. The recent publication of a guide to catfish culture in southern Africa (Hecht *et al.* 1988) is a benchmark document which

illustrates the truly "homegrown" nature of the catfish culture technology in South Africa.

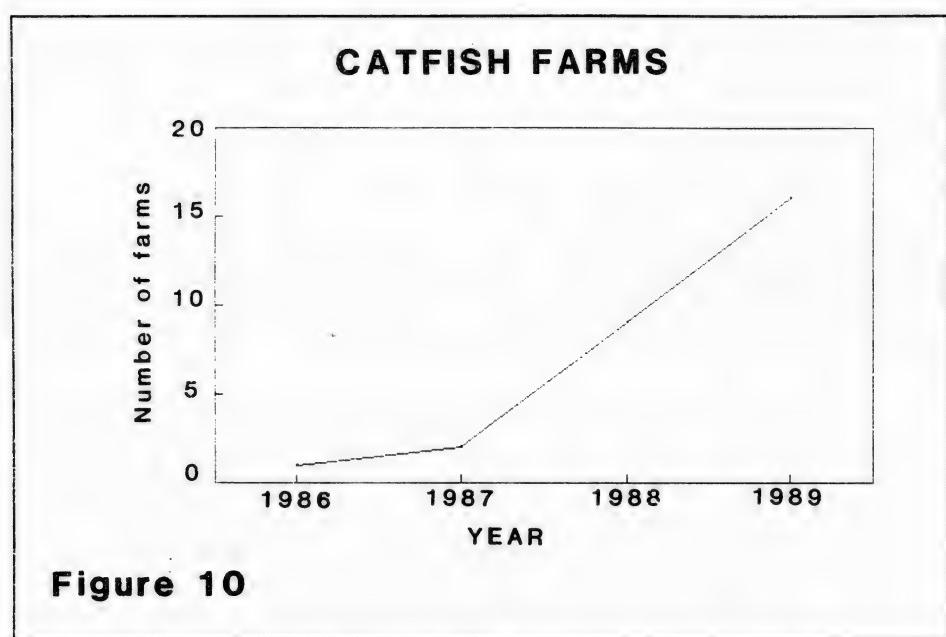


Figure 10

treating white spot once it has reached epidemic proportions have met with very limited success and are not considered practical on a large scale. Measures to improve fingerling survival are currently under investigation. Primary among them are cost effective ways in which to elevate ambient water temperatures, such as the use of plastic tunnels and heat exchangers.

Despite the good knowledge that exists regarding catfish nutrition there is no single dedicated facility which is capable of producing a large volume of catfish feed. The establishment of such a facility is currently being investigated by members of the industry.

Processing and marketing

The greatest challenge to the catfish industry lies in the development of products and markets. Although catfish are currently being sold successfully, and the present demand exceeds supply, the processing and marketing of the product has not yet crystallised into an established structure. Catfish producers are currently exploring a number of options which include the gate sale of fresh fish to the black rural market, distribution of a range of fresh and smoked products via wholesalers to restaurants, supermarket chain stores and fishmongers, and the canning of catfish as a pilchard substitute. At this stage producers are keeping their options open and experimenting with different products and marketing strategies. While high quality products can be produced from the fish, problems exist with regard to the popular perception of catfish amongst white South Africans. The obstacles to be overcome in catfish product development and marketing are by no means unique, and the respective experiences of trout farmers in South Africa and catfish farmers in the U.S.A. provide invaluable guidelines in this respect.

The qualities of catfish meat makes it particularly suited to various forms of processing. Catfish yield high quality boneless fillets of a unique texture and flavour. Due to the relatively high oil content of the meat, a very good smoked product can be produced. Processing and taste trials conducted by the Fishing Industry Research Institute (Wessels and Simmonds 1984) and private companies have produced very promising results with respect to canning and smoking. Catfish are currently marketed either in a chilled or freshly frozen form. Wholesale prices range from ca. R3.00/kg for gutted whole fish (frozen, head and skin on) to R7.50/kg for chilled or frozen fillets. A small proportion are smoked.

Constraints

Fingerling production is the major bottleneck in the evolving production cycle, largely due to mass-mortalities in nursery ponds caused by "white spot" (*Ichthyophthiriasis*) during periods of sub-optimal temperatures (less than 25° C). Attempts at

However, the value added style products are not yet being produced on a large scale. Packaging is mostly of a utilitarian nature suited to the requirements of the catering and wholesale trades. The largest catfish producer disposes of his fish in Johannesburg through the wholesale and distribution network of a large fishing company which is interested in promoting catfish products.

The products marketed to the restaurant and supermarket trades are sold as "catfish", a name which appears acceptable to the consumer. At the first AGM of the Catfish Growers Association it was resolved to avoid the name "barbel or barber" due to the negative associations attached to these names, however, it was agreed that potentially misleading names such as "red clipper" should not be adopted. A suitable Afrikaans equivalent of the name "catfish" has yet to be agreed upon. The only consumer resistance to catfish detected so far relates to the colour of their flesh. Larger fish tend to have a reddish colour, whereas consumers expect white fish fillets.

Market research by producers indicate a number of possible avenues. However, once a commitment has been made to a particular market, the farmer must gear himself to produce the volumes required. Due to the small size of the industry at the moment, farmers have been unable to produce the large volumes of fish required by the processors. They have also not yet generated enough return on their investment to purchase sophisticated processing and packaging equipment, or to initiate marketing campaigns that would be necessary to enter the added value product market. Producers do not, however, have any difficulty in disposing of their product via gate sales or through wholesalers and it is predicted that the more sophisticated markets will be penetrated as the industry grows.

Catfish Research

1. Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown.
2. Limnological Research Institute, University of the North, Sovenga.
3. Research Unit for Fish Biology, Rand Afrikaans University, Johannesburg.
4. Nagle Dam Hatchery, Natal Parks Board.

Veterinary Services

1. Fish Disease Unit, Veterinary Research Institute, Onderstepoort.

TILAPIA (Oreochromis and Tilapia species)

Tilapia culture has probably received a larger research input than any other group of aquaculture candidate species in South Africa, and yet the farming of tilapia remains a marginal undertaking throughout the region. The reasons for this relate primarily to its undeveloped market potential and to several life-history characteristics, the insistence by local farmers to produce tilapia in extensive earthen ponds as well as the lack of a commercial focus in the research that has been undertaken to date.

Production

Tilapia are currently produced as a sideline by catfish farmers and on a small scale in demonstration units in homeland states. Approximately 11 tons of tilapia, mainly Oreochromis mossambicus and a very small quantity of Tilapia rendalli, were produced in 1988 with a market value of some R33 000.

Some catfish farmers place a small quantity of tilapia into their catfish ponds. However, these fish are primarily regarded as a bonus to the catfish crop. No management is applied to these fish, nor are they budgeted for in catfish feeding schedules and production planning. Their presence compliments that of catfish, and growth and food conversion ratios of catfish are not affected by their presence. The yield of tilapia in polyculture with catfish accounts for up to 10% of total pond yield. During the 1988/89 catfish breeding season a shortage of catfish fingerlings resulted in a number of farmers stocking O. mossambicus as a substitute and the projected tilapia production for 1989 is 33 tons.

Demonstration fish culture units supported by the Department of Development Aid exist near Giyani in Gazankulu and on the Makatini Flats in Kwa Zulu as part of a broader rural development programme. The intention is that the demonstrated technology will be adopted by rural populations living in these areas in order to provide job opportunities, a "cheap" supply of food and financial independence. Tilapia are reared in combination with chickens or ducks and a small tonnage of each has been produced in these units. Tilapia are the preferred fish of the people in the rural areas and sell for R2.00 to R4.00 / kg.

Constraints

The main constraints regarding the intensive commercial production of tilapia relate primarily to the underdeveloped nature of suitable market infrastructure and the size heterogeneity of tilapia resulting from their precocious breeding style. Tilapia currently produced by commercial farmers are harvested regardless of size and sold as gate sales without any processing. To market tilapia in the formal fish market would require a larger average sized fish. This can be achieved in intensive tank culture using monosex populations. The technology for this form of tilapia culture has for a long time been perfected and practiced in Taiwan and Japan. However, the low price of tilapia has to date not justified the high initial capital expenditure and running costs of such facilities. Red tilapia may offer some hope for intensive culture due to its appealing appearance (possibly as a marine line fish substitute), however, an intensive and costly marketing effort would probably be required to establish its value on the market.

With respect to the place of tilapia farming (and that of other fish species) in rural areas, the initiatives of local development agencies would appear to be destined to a fate oft-repeated throughout Africa since the 1950's. While the research efforts by universities and development agencies in the homelands and the independent national states have in themselves been successful, the transfer of this technology to the rural populace has failed. This is unfortunate as the demonstration units in Gazankulu, Lebowa and Kwa Zulu appear to be viable (Hughes-Games and Batchelor 1988). However these units all rely on the energies and enthusiasm of research and development personnel for their sustained momentum. To date, no rural communities in South Africa (and probably in Africa) have adopted and independently sustained fish farming activities. The reasons for this are complex, however, they are to be found on the one hand in the motives and modus operandi of the promoting

agencies and, possibly, on the other in cultural traditions of the communities concerned.

Marketing and Processing

No formal channels exist for the sale of tilapia, however, informal gate sales by commercial fish-farmers and sales from demonstration facilities indicate that tilapia are the preferred fish of black rural populations and that a substantial market exists.

Tilapia Research

1. Department of Zoology, University of Zululand.
2. J.L.B. Smith Institute of Ichthyology, Grahamstown.

MULLET

The Amalinda Fisheries Station of the Cape Department of Nature and Environmental Conservation has for a number of years, under the direction of Dr A. Bok, been developing techniques for the culture of mullet (Myxus capensis, Liza richardsonii and Mugil cephalus). The culture of mullet is being promoted by the conservancy both for the purposes of freshwater angling and for extensive aquaculture.

Production

The large scale artificial spawning and rearing of mullet has not yet been perfected in South Africa. To date most of the fry provided for stocking purposes by the Amalinda Hatchery have been obtained from feral stocks. Mullet readily adapt to freshwater environments and due to their specialised feeding mode (the consumption of diatom rich detritus), they do particularly well in impoundments. Since 1982, Lake Mentz has been stocked annually with fry (mainly Mugil cephalus). A small tonnage of mullet (approximately 20 tons for 1988) is now being successfully harvested by a private fishing concern. These fish are gill net at a size of 2-4 kg. A number of smaller farm dams have also been stocked and good growth and survival has been reported. The extensive culture of mullet is seen as a very viable aquaculture option, however, the bottleneck in the production cycle remains the lack of fry. Due to the rapid advances that have been made in mullet culture elsewhere, particularly in the Far East it is probably only a matter of time before the large-scale propagation of mullet becomes a reality in South Africa (Bok 1988).

Markets

Markets for fresh mullet are not yet fully developed in South Africa. However, the market for dried mullet (bokkoms) is well developed in the Cape. Exploratory marketing of fresh mullet is being undertaken by a large fish distributor and a small but steady demand is reported to exist.

CARP (Cyprinus carpio)

Since the disastrous attempt to establish a carp culture industry in the early seventies (see Chapter 2), carp culture has remained a marginal enterprise.

Production

At least one fish farmer in the eastern Transvaal Lowveld is known to spawn and rear a small quantity of carp, although primarily for the sale of fingerlings. Techniques for the pond culture of carp are well established and no constraints exist in this regard. Estimated production for 1988 was five tons.

Markets

A small but steady market exists among the Jewish and European expatriate community. Demand for carp is highest during Passover and although a number of fish farmers supply carp to this market, most of the fish originate from wild stocks. The rural black market is not very receptive to carp, preferring species such as tilapia and catfish.

BASS (Micropterus spp.)

Both smallmouth (Micropterus dolomieu) and largemouth bass (Micropterus salmoides) were propagated for many years by the provincial nature conservation hatcheries for angling purposes. Due to the ecological damage caused by smallmouth bass, their continued distribution has been banned. In line with policies regarding the phasing out of the promotion of exotic species, the sale of largemouth bass fingerlings has also been discontinued by all provincial authorities with the exception of the Natal Parks Board. To meet the continued market demand a number of small private operators are now starting to breed bass.

Production

The production of bass fingerlings is a simple matter involving the placement of spawners in a breeding pond in spring. After spawning the adults are removed and the fry reared to fingerling size. There is a fairly large informal trade in bass fingerlings for the stocking of farm dams, however, its size is not known. The Natal Parks Board is the largest supplier of bass fingerlings and during the 1988/89 breeding season sold 59 000 fingerlings.

Markets

A high demand exists for bass fingerlings especially since the Cape and Transvaal nature conservation authorities stopped supplying fingerlings. The Natal Parks Board charges 21c per fingerling, however, due to the chronic undersupply of bass private breeders obtain prices as high as 50c per fingerling.

B. SHELLFISH

At present, the culture of shellfish is the only form of commercial mariculture practiced in South Africa. Oysters and mussels account for the bulk of production and only a small quantity of clams are produced. Good markets exist for all species both locally and overseas. However, due to a shortage of suitable culture sites the growth of the shellfish industry is limited. Protected waters required for shellfish culture are only found in a few bays and estuaries, and most of these are already subject to heavy use either as harbours or for recreational purposes. Unless technologies are developed to culture shellfish in more exposed situations, it is expected that South African shellfish production will reach a ceiling within the next ten years.

Because oysters and mussels require regular size sorting and grading, shellfish production is labour intensive, requiring a well organised system of production management. In terms of employment, shellfish producers make a valuable contribution to the local economies of small towns such as Knysna and Saldanha Bay where culture operations are centered. Between the ten existing shellfish culture operations over 300 people are employed. Because of the low cost of materials required for production (rafts, long-lines, racks, bags, etc.) labour costs make up the bulk of the production cost.

An ever present "sword of Damocles" to the shellfish industry is that of pollution both with respect to direct shellfish mortalities, and perhaps more importantly, the possible risks to the consumer. The major South African mariculture sites are situated in the vicinity of harbours and often near factories. The possibility of effluent discharge from these sources is thus an ever present threat. Because of their filter feeding habit, resulting in the concentration of pollutants, shellfish are highly sensitive to any form of industrial pollution. The public are also highly sensitive to any perceived health threat from eating shellfish. It is therefore very important for the industry that the consumer feels "comfortable" about the product. The effects of a perceived health risk were graphically illustrated by the decline in oyster sales following the claim in 1982, that an oyster in a Durban restaurant was found to contain the cholera virus (Genade 1986). Following the cholera scare, the Knysna Oyster Company installed an ultra-violet water sterilisation unit in its purging system to allay further fears that oysters might contain toxic pathogens.

Related to the health aspects of shellfish products is the ever-present danger of red tide on the west coast which may cause Paralytic Shellfish Poisoning (PSP). Because of this threat, oysters and mussels are subject to a routine bioassay to test for the presence of toxic substances in their flesh. This is regarded as an essential safeguard for the consumer as well as the image of the industry even though it adds significantly to production costs.

OYSTERS (Crassostrea spp.)

Oyster culture in South Africa has a long history in South Africa (see Chapter 2). The culture technology was developed mainly by the now defunct Fisheries Development Corporation, which conducted a long term research programme to promote oyster culture. Efforts to culture the Cape rock oyster Crassostrea magaritacea on a commercial scale met with limited success due to unreliable spat falls and slow growth rates. The pacific oyster Crassostrea gigas therefore replaced C. magaritacea as the cultured species during the 1970's. Today, oyster culture represents one of the simplest and most profitable aquaculture technologies in South Africa.

Production

Oysters are cultured in plastic mesh bags suspended in the water column by means of racks, long lines or rafts. Spat are imported either from England or Chile and ongrown to market size (30-100 grams). The high costs of erecting and running a hatchery, as well as the risks attached to seed oyster production have favoured the continued importation of spat since the closure of the FDC hatchery at Knysna in 1985.

The introduction of C. gigas in the 1970's stabilised oyster production. Approximately two million oysters were produced annually throughout the seventies and early eighties. During the last five years, six new producers have entered the market.

Consequently, oyster production has risen steadily (Fig. 11). Nine oyster farms now exist in South Africa and Namibia with individual production outputs for 1988 ranging between 300,000 and 2 million oysters. In 1988, 4.6 million oysters were produced with an estimated retail value of R6.4 million.

OYSTER PRODUCTION

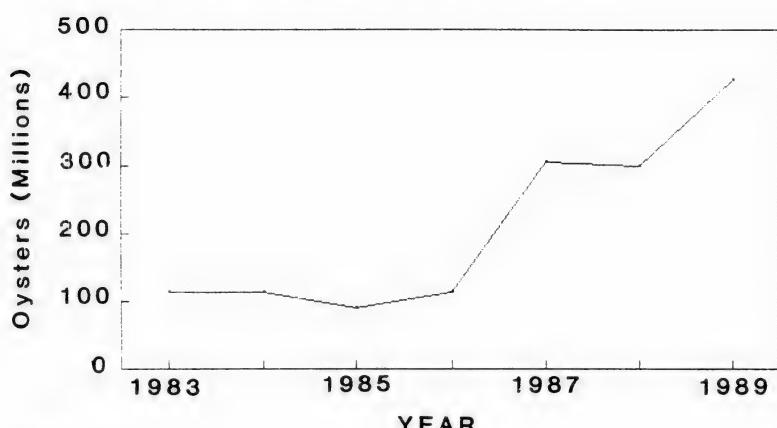


Figure 11

projected production figure for 1989 is 6.5 million oysters. Oyster production is expected to grow at its present rate for the next 3-4 years as the present operations build up to full production capacity.

Constraints

The only serious production problem that producers experience is parasitism by the polychaete mud-blister worm (Polydora species). The worm borrows into the shell and forms a mud blister inside the oyster. Although this does not cause mortality, oysters are rendered largely unsalable due to the unappetising appearance of the mud blister. All oyster culture operations report the presence of Polydora, however, its incidence is worst where oysters are cultured close to muddy sediments. The only known treatment for Polydora is exposure to air and at Knysna, where Polydora infestation is particularly severe, producers have been forced to adopt a tidal rack system of culture so that the oysters are exposed to the atmosphere for part of the tidal cycle. This is not an optimal solution because of the resulting slower growth rates. It is therefore highly desirable that an effective treatment be found to combat Polydora infestation. Research on the Polydora problem is currently being conducted at the University of Cape Town.

Spawning at certain times of the year is reported to be a minor problem which reduces oyster quality. Reports from the industry, as a whole, revealed that it is also severely constrained by disabling legislation, in particular as regards the current policy of not allowing any further development in estuaries.

Marketing

All oysters are marketed fresh which precludes the need for sophisticated processing facilities. Marketable oysters are size graded and packed into wood or polystyrene boxes for transport to buyers. Fresh oysters can be kept under refrigeration for at least a week without detrimentally affecting their quality. Oysters are sold to wholesalers or direct to the restaurant trade. Demand exceeds supply and good prices are obtained. In 1989 producers obtained between R0.45 and R1.00 per unit for 30 to 100 gram oysters, respectively. The South African fresh oyster market is expected to be indefinitely undersupplied due to the limited number of culture sites available.

MUSSELS

The culture of mussels in South Africa is a very recent innovation (ca. 1985) which has been highly successful. In terms of tonnage produced, mussels already exceed the combined production of all other forms of aquaculture in South Africa.

Production

The dramatic growth in South African mussel production is illustrated in Figure 12. The Spanish raft and rope technology for mussel culture has been transferred and successfully adapted to local conditions.

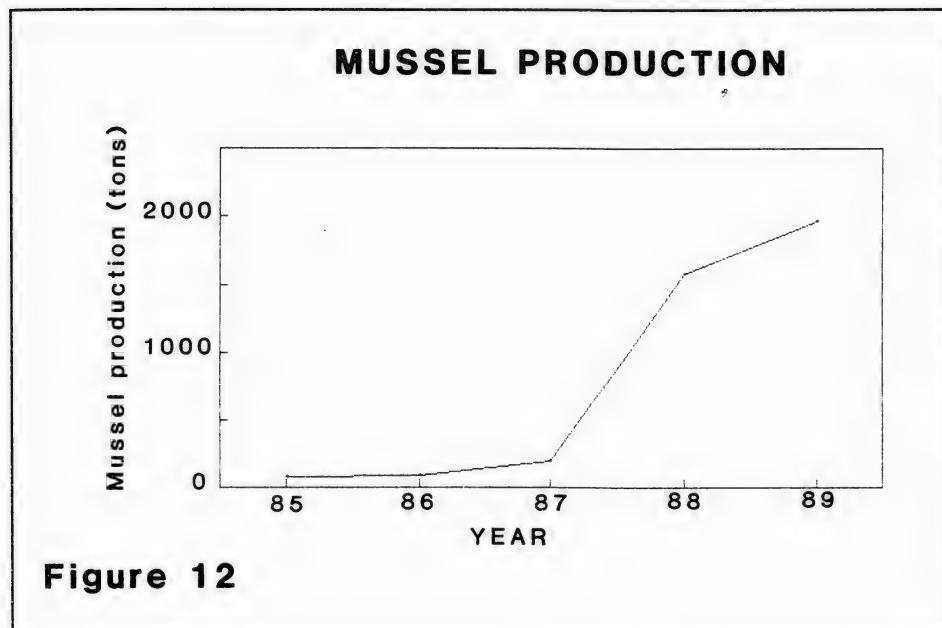


Figure 12

Three species of mussel are presently cultured. These include the Spanish mussel (*Mytilus galloprovincialis*), an introduced species which accounts for the bulk of production, and the indigenous black and brown mussels (*Choromytilus meridionalis* and *Perna perna*) which make up the balance. *M. galloprovincialis* is favoured because of its

superior colour and flavour. Mussels are reared to a marketable size of 20-22 grammes, in approximately six months.

Seed mussels are collected from the wild and bound onto ropes. These are suspended in the water column either from floating long line or raft systems. Rafts have the advantage of providing a stable work platform and are more durable than long lines. Long lines consist of a system of ropes and buoys and are cheaper to install than rafts. However, the longline systems have to be serviced from a boat which makes the installation and removal of mussel ropes more difficult during inclement weather. Due to the strong prevailing winds at Saldanha Bay and Port Elizabeth, the conditions under which mussels are reared in South Africa are among the more exposed in the world.

Constraints

Due to the settlement of fouling organisms (eg. redbait (*Pyura*), mussel spat, barnacles) mussel ropes require regular maintenance and rebinding which increases labour costs and complicates production management. One enterprising producer has turned the fouling problem to his advantage by marketing the red bait. The spawning of mussels which usually occurs in spring with increasing water temperatures adversely affects product quality since the flesh weight of the mussel is drastically reduced. The flesh weight of good quality mussels should be over 30% of total mussel weight. Producers interviewed reported that mussels were marketed successfully regardless of condition.

Processing and Marketing

The processing and marketing of mussels is still in a state of relative flux and a wide variety of products are currently being produced. Unlike oysters which are only sold fresh, the bulk of mussel production is cooked and processed into various forms. Mussels are processed and distributed through different strata of the seafood market. Outlets for mussels include:

- * direct marketing by producers of whole fresh or cooked half shell mussels to hotel, restaurants and supermarkets.
- * the sale of cooked, frozen half shell mussels to wholesalers and the catering trade,
- * the sale of fresh mussels to processors for canning or processing into other value added products such as pate's, mussels in sauces, seafood mixes etc.

Because markets are still being explored and production has increased rapidly, some marketing bottlenecks have been experienced. However, all producers report that the market is very receptive to mussel products and that the demand is expected to increase. Producers obtain in the region of R5.00/kg for whole fresh mussels.

CLAMS

A small quantity of clams are produced, namely the indigenous Mactra glabrata and the imported Manila clam Tapes philippinarum

Production

Mactra are extensively produced at Saldanha Bay. The operation is extremely rudimentary, and should strictly be classed as a feral fishery. Naturally spawned clams that grow in the substratum are managed and harvested on an ongoing basis. Twenty five tons of Mactra were harvested in 1988. The manilla clam is being reared on a trial basis by a producer in Saldanha Bay and one in Namibia. Spat is imported from the United Kingdom and ongrown in a similar fashion to oysters.

Markets

A receptive market is reported to exist for both Mactra and Manilla clams. All clams currently produced are sold to the restaurant and hotel trade.

C. AQUATIC PLANTS

WATERBLOMMETJIES (*Aponogeton distachyos*)

Waterblommetjies have for centuries been informally harvested from streams and dams in the western Cape. Traditionally a "poor mans" food, they have now become a sought after gourmet commodity, proudly regarded as being part of the South African popular culture. The promotion of the image of waterblommetjies in recent years has largely been a marketing effort that has gone hand in hand with the development of techniques for their intensive commercial cultivation. Intensive cultivation techniques are now fairly well established and production is expected to increase substantially over the next few years as the market expands.

Production

Techniques for the cultivation of waterblommetjies were developed in the early 1980's by the Faculty of Agriculture of Stellenbosch University in association with interested producers. Waterblommetjies are a seasonal crop and harvesting begins in early April in small quantities and continues through the winter until September - October when peak production is achieved. In November yields fall rapidly as flowers die. Prices are highest at the beginning of the season (ca. R3.00 / kg - producer price), and as seasonal production increases prices fall to around R1.50/kg in October. A production output of 5-10 tons/ha/year is achieved, however, under experimental conditions in concrete ponds yields equivalent to 24 tons/ha/year have been obtained. Six producers practice intensive waterblommetjie culture and their expected production for 1989 is approximately 250 tons (Mr A. Lubbe, Langeberg Coop. Ltd., personal communication). This figure is considerably higher than the reported figure of 20 tons for 1982/83 (Safriel and Bruton 1984) which reflects the growth of the industry. The estimated retail value of the 1989 crop is R1.75 million.

Waterblommetjies are cultivated in shallow ponds of one metre depth. The quality of the flowers is all important and therefore ponds are constructed with a maximum length of 55 m in the direction of the prevailing wind to reduce wind waves, which disturb the pond sediments and muddy the flowers. Waterblommetjie harvesting is labour intensive and to make the most efficient use of labour, it is important that large, good quality flowers are cultivated. A labourer will typically cut 350-380 kg of large flowers per day, but only 60-90 kg if the flowers are small. It is therefore essential that the rows of plants are constantly thinned out and well maintained to prevent overcrowding and the consequent development of small flowers.

Constraints

Fouling of plants by Spirogyra is a major problem that is costly to treat. One producer reported that to treat his ponds with methyl bromide cost R3000/ha.

All the major producers that were interviewed stated that the lack of an established production technology has impeded the growth of the industry. It is regrettable that the research effort conducted at Stellenbosch University has been terminated due to a lack of research funding. Producers are fairly secretive about their operations and no producer association exists. For the infant industry to become truly established, continued research support, as well producer cooperation, is required.

Processing and Marketing

The Langeberg Cooperative Ltd. has played a leading role both in terms of the development of the culture technology and with respect to processing and marketing. Waterblommetjies are marketed either as fresh, frozen, preserved or as soups. Producers obtain premium prices for fresh waterblommetjies through gate sales, and distribution through wholesalers. When production peaks in September-October, the fresh market becomes oversupplied and the surplus is sold to factories for processing into soups and other products. Fresh waterblommetjies retail for about R7.00/kg and have a fairly upmarket image. One producer expressed the opinion that waterblommetjies should be priced more in line with other vegetables which would allow a greater volume to be sold.

D. REPTILES

CROCODILES

The culture of crocodiles is a unique undertaking that has attracted a great deal of interest in southern Africa. Although some R25 million has already been invested in crocodile farming and its tourist

aspects (Marais and Smith 1988), actual production is still very much in its infancy. As existing farms come into full production, sales of crocodile skins are expected to increase dramatically. It is equivocal whether crocodile farming is actually a form of aquaculture because the animals do not spend a great deal of time in the water. However, crocodile farmers in South Africa have traditionally associated themselves with aquaculture and it is for this reason that we included the information on crocodiles.

Production

Crocodile production has been rather slow to develop. The primary reason being that South Africa is one of the few crocodile producing countries in which the farmers do not obtain young crocodiles from the wild and have to rely entirely on captive breeding. It takes approximately six to seven years to rear a crocodile to breeding size. In order to generate a cash flow during the startup period, most crocodile farms rely on the tourist trade. Between 1978 and 1988, the number of crocodile farms in southern Africa increased from two to 25, however by 1989, only about 25% of these had marketed skins and other crocodile products. The production figures of the crocodile industry, as reflected by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) statistics

are illustrated in Figure 13. These figures are somewhat misleading as many live crocodiles are currently changing hands within the developing industry to be reared as broodstock.

The value of crocodile products sold in 1988 was approximately R900 000. Sales of skins accounted for the bulk of this figure, the current price being U.S. \$5.00 / cm, measured across the belly. By products

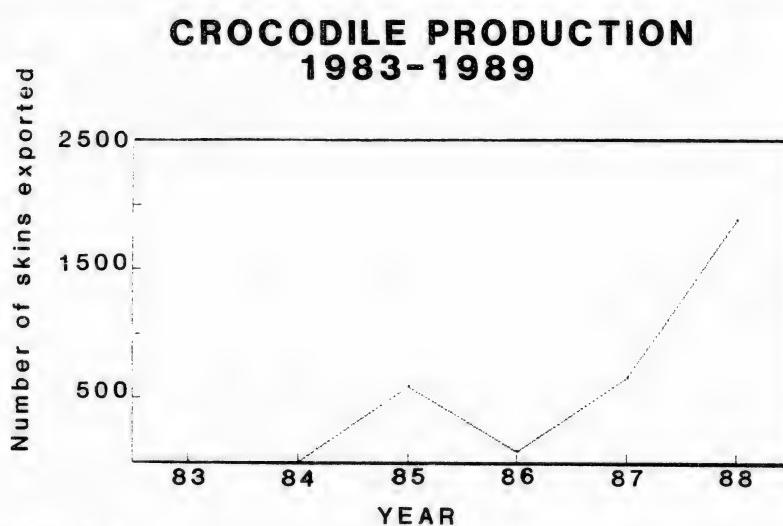


Figure 13

(skulls, backskin, meat and others) represent approximately 20% of the value of each animal. The combined products of a good animal with a 30cm belly skin are worth about R500. Breeding animals (longer than 2.2m) are valued between R5000 and R6000 each.

Crocodiles breed in spring and eggs are laid in specially prepared nesting sites. Once laid, the eggs are removed and incubated under controlled conditions of temperature and humidity. After hatching, well controlled environmental conditions, balanced nutrition and minimal stress are essential prerequisites to ensure successful rearing to the juvenile stage. Because the belly skin is the main product, it is important that juveniles are kept on a suitable substratum to ensure that the skin is not damaged in any way. Under ideal conditions it takes 18 months to rear a crocodile to a marketable size of 1.5m (ca.18kg), although the industry average lies between 24 and 36 months.

Constraints

In contrast to other branches of aquaculture which have inherited a great deal of technology from overseas or enjoyed research support in South Africa, crocodile farming techniques have been developed by trial and error by the producers themselves under local conditions. It would appear that despite the existence of relatively good information on the requirements of crocodiles, some expensive mistakes have been made due to a lack of communication and coordination within the industry. To date, technical problems and a lack of a proven technology have been the main factors hampering production. Typical production problems include stress, disease, low fertility of broodstock, and mortality of hatchlings, all of which relate to system design and management. The industry is now receiving a measure of research support from the University of Pretoria where a "Crocodilian Study Group" has been formed in association with interested producers to promote crocodile farming skills and to disseminate information.

Broader constraints include a chronic lack of broodstock and insecure feed supplies. Crocodile farms rely on abattoir waste and other sources of offal which are usually obtained informally and free of charge. As the industry grows a more secure source of feed will have to be found. Obviously, this would affect production costs and ultimately the value of the skins and other products.

Due to the relatively high temperature requirements for optimal growth of young crocodiles, heating costs of hatcheries form a significant part of production expenses. A variety of heating systems (electrical, diesel burners, heat pumps, solar and gas) are used by different producers to regulate environmental temperatures, indicating a need for research to develop cost-effective heating systems.

Processing and Marketing

A sophisticated international system of marketing and distribution exists for crocodile skins. Due to the distinctive hide characteristics of the Nile crocodile, its belly skin is much sought after. All skins are marketed under the jurisdiction of CITES. Skins are processed in Germany using sophisticated tanning techniques and then sold to the manufacturers of upmarket shoes, handbags and other items.

The sale of by-products is an informal undertaking with their novelty value being an important selling point. Skulls, teeth, and backskin are sold as curios and complement the tourist component of crocodile farming. Crocodile tail meat has a unique texture and flavour and has received a fair amount of positive promotion in the media. The flesh is white, low in calories and fat and is now fairly common on certain menus, especially in game lodges.

5. PROSPECTIVE SPECIES

The previous chapter dealt exclusively with those species currently farmed in South Africa on a commercial scale. However, since 1984 some significant advances in terms of research and development have also been made on several prospective candidate species, which now stand on the threshold of commercial production. It was therefore decided to provide a brief overview on the research and the current status of these developments. Most of the recent interest has been focused on the development of the culture technology of marine species. The reasons for this are primarily market related. Commodities which can be farmed in seawater inherently have a higher value per kilogram than those farmed in freshwater, with the exclusion of marron and freshwater prawns (two of the prospective candidate species) and trout. It is interesting to note that almost without exception, lucrative markets already exist for these species and the major constraints to their full scale production relate either to appropriate sites or culture technology.

Those species currently on the threshold of commercial production in South Africa include abalone, Atlantic salmon, penaeid prawns, freshwater prawns, marron, brine shrimp, blue-green algae, seaweed and grass carp.

ABALONE (Haliotis midae)

Abalone or perlemoen of the genus Haliotis are highly prized commodities on the local as well as on foreign markets. A small abalone fishery exists in South Africa, which in 1988 yielded approximately 640 tons (SA Fishing Industry Handbook and Buyers Guide, 1989) (this figure excludes those taken by sport divers, who are restricted to five per man per day). Over 90% of the harvest taken by commercial fishermen is exported to the Far East. Declining abalone fishery yields worldwide have stimulated the development of rearing techniques, and abalone are now successfully cultured in a number of countries. The leading countries in the development of abalone culture technology are Japan, the U.S.A. and Taiwan.

Current research and production status

Owing to the successful development of intensive abalone farming techniques elsewhere, particularly in California, Japan and Taiwan, a great deal of interest has recently been shown for the establishment of such an industry in South Africa. What makes abalone culture particularly attractive in South Africa is that it is an onshore operation using pumped sea water. Site availability should therefore not be a limiting factor. Furthermore, the growth of the industry in most other countries is limited due to overpopulated coastal areas and polluted waters.

The technology for abalone culture is well established and its application in South Africa is mainly a matter of technology transfer and its subsequent adaptation to local conditions. Three research institutions, Rhodes University, University of Cape Town, and the CSIR's National Research Institute

for Oceanology at Stellenbosch, have recently initiated research programmes in association with the private sector to develop the technology for the culture of the South African species, Haliotis midae. Research at the University of Cape Town is primarily directed towards the establishment of optimal rearing conditions, while the CSIR's division at Stellenbosch has recently perfected the technique of producing seed abalone. The technology for the spawning and rearing of seed abalone was originally developed in the early 1980's at the FDC hatchery in Knysna (Genade *et al.* 1988). The primary biological constraint to successful abalone culture in South Africa is the availability of an adequate and suitable source of feed. The primary natural food source is kelp (Ecklonia maxima). While fresh kelp and other seaweeds would obviously be the logical choice as a feed the Department of Environment Affairs currently does not allow the harvesting of fresh kelp and other seaweeds (although this is presently being reconsidered). However, even if concessions were granted to harvest fresh kelp and other seaweeds, the pure logistics of harvesting the required quantities on a daily basis would be a severe limiting factor. To produce one million medallion sized abalone a year (ca. 85 tons) would require approximately 9 tons of fresh kelp per day. Rhodes University has therefore undertaken to development a cost-effective artificial feed to facilitate the establishment of the industry.

Other candidate abalone species are the Californian red abalone, Haliotis rufescens and the Taiwanese Haliotis diversicolor supertexta. Both are fast growing species for which an established culture technology already exists. H. rufescens is a cold water species that would probably perform better on the South African west coast than the local species. Small quantities of H. rufescens have been imported twice on a trial basis, but none of these animals exist now. Considering the growth rate of the indigenous species in various regions along the coast (R. Tarr, Sea Fisheries Research Institute, pers. comm.) we recommend that the culture of H. midae be undertaken on the south west, south and south east coast, between Cape Hangklip and East London. H. diversicolor, on the other hand, is a warm water species that might be suitable for culture along the Transkei coast and in Natal, while H. rufescens, a cold water species, would probably do best on the west coast.

Considering the current research input and the commitment of the private sector we are confident that the commercial farming of Haliotis midae in South Africa will be a reality within the next five years.

Markets

Lucrative markets exist in Japan and current (1989) retail prices are in excess of US \$70.00 per kilogram for abalone steak. Live medallion sized animals consumed in Japanese sushi bars fetch the highest prices.

ATLANTIC SALMON (Salmo salar)

The huge success of salmon farming in the northern Hemisphere (see Chapter 1) has led to the successful introduction and culture of Atlantic salmon in a number of southern hemisphere countries, viz. Chile, Falkland Islands, New Zealand and Tasmania. While certain areas on the south and on the west coast of South Africa may be suitable for salmon culture, a careful evaluation of possible sites is necessary before salmon culture is deemed feasible.

Current research and production status

Atlantic salmon are spawned and reared in freshwater until they smolt between one and two years of age (smolting is a process of physiological change which prepares salmon for life at sea). Upon smolting they are transferred to floating sea cages and reared to a market size of 4-5kg over a two year period. Enormous strides have been made in cage technology and highly sophisticated cages that are suitable for placement in fairly exposed locations have been developed.

In South Africa salmon culture is a possibility in onshore facilities and in sheltered or semi-exposed coastal sites. If onshore facilities are considered, the economics of high initial startup costs and running costs (pumping) would have to be weighed against the possible return on investment. Onshore facilities in Canada have however shown themselves to be economically viable. The feasibility of salmon on the west coast needs to be carefully considered due to water quality fluctuations that result from periodic algal blooms and upwelling events. A preliminary evaluation of certain areas on the west coast also indicated that the high loading of suspended particulate matter which is often present in the water would be detrimental to salmon. Several sites on the south and southwest coast between False Bay and Mossel Bay would probably be more suitable.

Markets

Despite the massive growth in the production of farmed salmon, global prices have remained fairly stable and a high demand exists for smoked and tinned salmon in South Africa. Official statistics show that 58 tons of salmon were imported into South Africa in 1988. We believe that this is an underestimation, but it nevertheless shows the potential for import replacement of this highly priced and luxury commodity. Due to the high demand for smoked salmon, whole frozen salmon are imported, smoked and packed locally. In response to the demand for high quality, fresh smoked salmon, large trout are currently being smoked and thinly sliced in the style of salmon. Under the current economic conditions South African produced salmon could also become a significant earner of foreign exchange.

PRAWNS (MARINE AND FRESHWATER)

The culture of marine prawns has been one of the global success stories in aquaculture. Present world production exceeds 85,000 metric tons (Nash 1988), and in recent years the technology for their culture has advanced rapidly.

Current research and production status

The potential of marine prawns as commercial candidate species has long been considered in South Africa (A. de Freitas, Oceanographic Research Institute, Durban, pers. comm.) and a significant amount of research has been undertaken, originally by the Fisheries Development Corporation at the Port Elizabeth Museum and at Amatikulu, followed by the Oceanographic Research Institute in Durban to promote the establishment of a culture industry.

The two marine species with the highest culture potential in South Africa are Penaeus monodon and Penaeus indicus, both of which occur off the Natal coast. The technology for penaeid culture is now well established and has been adequately described in the literature. Prawns require fairly high temperatures (20- 30° C) and good water quality. Highest growth rates are obtained in brackish water (20 - 30 ppt) and therefore a supply of both sea and salt water is desirable to regulate pond salinity. Very few suitable sites exist for marine prawn culture and access to these is seen as a major constraint to the development of the industry. Serious consideration should also be given to making use of thermal effluent plants along the coast.

The freshwater prawn Macrobrachium rosenbergii has also attracted much interest as an aquaculture candidate and research has been conducted at a number of centres to develop its aquaculture potential under local conditions. In 1980 the first 200 post larvae were imported from Taiwan by the Corporation of Economic Development and nurtured at the Lowveld Fisheries Research Station at Marble Hall. A second consignment of 8000 post larvae was received by Marble Hall in 1981. In 1982 and 1983 a pilot project was initiated at Lisbon Estates in the eastern Transvaal Lowveld. Environmental conditions for the culture of Macrobrachium rosenbergii in South Africa are however regarded as marginal due to the high temperature requirements of the animal (20-30°C). However, the

experiment in the Lowveld demonstrated that nine months of growth can be expected. At stocking densities of 3.5 - 7 individuals per square metre, extrapolated yields of 1.2 tons/ha/year were achieved in 0.3ha ponds (Taylor 1985). Larvae are reared in brackish water in a hatchery and juveniles are grown out in freshwater earthen ponds. Relatively large pond areas are required to achieve a substantial production due to the relatively low densities at which the prawns are reared. Reliable semi-skilled labour is required to carry out constant pond cropping. A serious problem, but not unsurmountable, under South African conditions is predation by the platanna (*Xenopus laevis*) and by various birds.

Research into the culture potential of local Macrobrachium species is now also in progress at the University of the North (Qwa Qwa Branch) (L. Taylor, University of the North, pers. comm.). The indigenous M. vollenhovenii grows to an acceptable size (up to 70g), however, nothing is yet known about its performance under culture conditions.

The untested technology for the large scale culture, under South African conditions, of both marine and freshwater prawns, several other minor and major biological and technical problems, a paucity of suitable sites and high initial capital costs, have until recently discouraged investors. However, the development of a commercial penaeid farm has now been initiated on the Natal north coast (Amatikulu Hatchery), and freshwater prawns (Macrobrachium rosenbergii) are being reared on a trial basis in the Transvaal Lowveld (Blyde River Aquaculture).

Markets

Despite the dramatic upsurge in world prawn production, a highly lucrative market exists for prawns. In 1988 South Africa imported 1167 tons of prawns, which is an indication of the size of the existing local market. Penaeid prawns currently retail for between R15.00 and R50.00 per kg depending on size and quality. Markets also exist for Macrobrachium in South Africa and a small quantity is currently imported which currently retails for approximately R20.00/kg.

FRESHWATER CRAYFISH OR MARRON (Cherax tenuimanus)

Despite its controversial conservation status, the introduction of the Australian freshwater crayfish or "marron" into South Africa in 1984 aroused a great deal of excitement amongst the aquaculture community (Walmsley 1987). A number of ventures were started in the hope of marketing marron, however, most have ceased to exist, and those that still do appear to be no nearer to marketing their product than the original importers some five years ago.

Current research and production status

Marron farming in Australia and elsewhere seems to be in a sensitive stage where entrepreneurs are reluctant to publicise details of their success or "lack of success". The potential of marron farming in western Australia was realised in 1976, but since its inception about 10 years ago it has not been successful. In 1987 there were eight registered marron farmers in Australia and the total production figure for 1986 was a mere 2.7 metric tons. It would appear that the major activity of marron culture in western Australia revolves around the production of juveniles for restocking purposes (Walmsley 1987).

On paper, marron possess some favourable aquaculture attributes (Hecht 1987). They eat detritus (compost), have a temperate temperature requirement and can potentially be grown to a marketable size in 18 months. In South Africa, as in Australia, we believe that a lack of knowledge of the requirements under captive conditions of the animal, inexperience on the part of producers and an untested culture technology are the primary reasons for the failure of the industry. Furthermore, some biological characteristics of the animal cast serious doubts over its suitability as an aquaculture

candidate. Notable amongst these are its low reproductive output and, like most crustaceans, it is a highly territorial and cannibalistic species. The local marron farmers interviewed had over a few seasons failed to build up a substantial breeding stock of animals, let alone market them. Unaccounted mortalities among adults, probably due to cannibalism during the moulting stages, were seen as a major problem. It is our opinion that unless further research is undertaken to develop a viable culture technology, the future of marron culture in South Africa looks bleak.

Out of eight farms, which by 1987 had obtained the necessary permission from the provincial conservancies, only two have successfully bred marron.

Markets

Marron is a gourmet food item. Consequently a local market for marron would no doubt exist, if it could be farmed successfully (A. Stricke, Kroondal and E. Bell, previous owner of Amanzi Marron Farm at The Wilderness, pers.comm.) and it would appear that the French market is also wide open to the successful marron farmer. In 1987 a retail price of \$30 per kg was realised in Australia.

BRINE SHRIMP (Artemia spp.)

Brine shrimp, particularly the nauplii of Artemia salina are one of the most important feed items used in the rearing of larval fish in commercial fish hatcheries around the world. In South Africa there are numerous hypersaline pans and other water bodies which contain natural populations of brine shrimp which offer possibilities for extensive culture. At least one entrepreneur is known to be currently initiating such an enterprise.

Current research and production status

The productivity of natural brine shrimp populations can be regulated through the management of certain water quality parameters (mainly salinity) and supplemental feeding. Natural brine shrimp populations may reproduce parthenogenetically or sexually (cyst formation) depending on the prevailing environmental conditions.

Indigenous brine shrimp occur in salt pans in the western Orange Free State and Northern Cape as well as in evaporation ponds of salt works (eg. at Coega Salt Works near Port Elizabeth). The instar larvae of the local varieties of Artemia are larger than those of the northern hemisphere species, Artemia salina. Consequently they would only be suitable for the rearing of certain types of larval fish with large mouths (eg. Clarias gariepinus). The introduction of the smaller, more marketable, Artemia salina is therefore currently under investigation.

Markets

As mentioned above brine shrimp are widely used as a larval fish food because of the ease with which cysts can be transported and hatched. Cysts are harvested from wild populations in a number of countries and sold in a dry form in hermetically sealed tins. In the cyst form the animal has an almost indefinite shelf life, without affecting quality. When brine shrimp larvae are required, the cysts are hatched over a 24 hour period in saline water. Other products include brine shrimp flakes, frozen brine shrimp, brine shrimp paste and decapsulated eggs. All brine shrimp products currently sold in South Africa are imported and retail for about R120 / kg. Import statistics do not reveal how much Artemia is imported into the country.

BLUE-GREEN ALGAE (Spirulina platensis)

Spirulina platensis is a single cell blue green algae suitable for human consumption and as a supplement for animal feeds. It was known to have been consumed by the ancient Aztec's in South America and more recently has been promoted as a health product throughout the western world. It is currently being produced on a small scale by a producer in the Orange Free State.

Current research and production status

Spirulina is grown in a hypersaline medium (Zarouk's Medium) and has an optimum temperature requirement of 20-40°C. Under natural conditions a production of 12-30 tons/ha/year (dry weight) may be realised (Safriel and Bruton 1984). Due to the relatively large cell size of Spirulina, in comparison to other single celled algae, it is harvested with relative ease using fine mesh screens on a continuous basis. Problems however still exist regarding the efficient bulk drying of the algae.

Market

Spirulina has a relatively high protein (65-70%), beta carotenoid and vitamin content and is marketed as a health food mainly in pill form. In 1984 sun dried Spirulina fetched between R100 and R200 / kg.

GRASS CARP (Ctenopharyngodon idella)

Grass carp were imported into South Africa in 1967 as a macrophyte control agent in large eutrophic impoundments (Schoonbee *et al.* 1978). Their distribution is currently prohibited in all provinces except Natal where they are bred and sold by the Natal Parks Board.

Current research and production status

Grass carp were first spawned in South Africa by means of hormonal induction in the late 1970's which facilitated the production of large numbers of fry (Schoonbee *et al.* 1978). Although natural spawning of grass carp has not been recorded in South Africa, fears of the fish establishing wild breeding populations led to the banning of their distribution in the Cape, O.F.S. and Transvaal until such time as sterile triploids are available. The Natal Parks Board also intends producing triploids in future.

A sugar farmer on the south coast of Natal is currently developing an intensive grass carp production unit. It is intended to feed the fish on sugar cane tops and will hopefully be disposed of via gate sales.

Market

A very high demand exists for grass carp fingerlings for the purposes of weed control. If the conservation authorities were to allow private breeding of these fish, this market would definitely be viable and exploited by farmers. We are of the opinion that grass carp as a table fish would however be a non starter.

SEAWEED (Gracilaria spp.)

For many years Gracilaria has been harvested at Saldanha Bay and Luderitz. More recently, a company involved in the harvesting of washed up seaweed initiated production trials involving the extensive culture of Gracilaria in sheltered lagoons and intends expanding into intensive commercial production.

Techniques for the culture of Gracilaria are simple and have also been fairly well researched in the Far East (Santelices 1989). As is the case with other mariculture operations, site availability is the prime limiting factor. A lucrative market, centered in the East, exists for products made from Gracilaria, primarily sodium alginate.

As mentioned earlier the species discussed above are those which are on the threshold of commercial production. Obviously these are not all the species that can be considered as candidates for commercial aquaculture in South Africa. Organisms such as several marine fish (eg. leervis, rock cods, sparids, kabeljou etc.), sea urchins, other seaweeds and bivalves as well as numerous of the smaller indigenous freshwater fish have potential as aquaculture species either as food or ornamental species. However a comprehensive research programme would have to be initiated to develop the culture technology for each of these species.

6. CONCLUSIONS

South African aquaculture has had a lengthy lead period. This survey has however revealed that the growth of the industry, since the early 1980's, has now entered the exponential part of the logistic learning curve. In fact the growth of the industry has been far greater than expected at the outset of this study. The tenfold increase in total production between 1980 and 1988 bears witness to this fact. We predict that the present growth phase of the industry, in terms of annual production, will in all probability be maintained for at least the next five years as the recently established, and prospective ventures reach their full production targets.

However, as and when more threshold species become truly commercial, coupled with more enabling legislation and further developments in culture technology, South African aquaculture will in all probability continue to grow at a steady pace well into the 21st century. The rapid growth of aquaculture in South Africa is not a local phenomenon or aberration, but part of a global growth phase, reflecting "the coming of age" of modern aquaculture technology.

During the survey we came across several instances of gross overcapitalization and inefficient as well as poor planning. Prospective entrepreneurs should therefore make greater use of recognized consultants. Not only would this be money well spent but it would also play an important role in ultimately portraying an improved image of the industry as a whole.

This study has defined the status of the various branches of aquaculture in South Africa. A summary of the state of development for each species is presented in Table 7. Probably the most important fact that emerges from this table is that all successfully cultured species are high unit value products. This should serve as a clear indication to prospective aquaculturists that market factors are of overriding importance when deciding on a candidate species. In a nutshell, during the decision making phase, the market demand of a candidate species is of greater importance than any other consideration. This principle is amply demonstrated by the carp and tilapia farming initiatives. Despite the existence of well established culture technology and the availability of suitable sites these species have not become commercially viable simply because of poor markets. It was therefore pleasing to note that all threshold species, with the exception of grass carp, are high value products for which well developed markets already exist.

The determining factors for the successful commercial farming of the threshold species are largely technological. A continued and dedicated research input is regarded as an essential prerequisite. We predict that within the next five years the current research and development effort on abalone, atlantic salmon and marine prawns will be successfully translated into practice with significant production volumes.

Table 7. Status of existing and threshold aquaculture species in South Africa
KEY:

Markets

- *** Well developed markets
- ** Good potential, product not yet widely distributed
- * Poor or underdeveloped markets

Culture technology

- *** Well established commercial technology
- ** Transitional between experimental and commercial
- * Experimental

Sites

- *** Many sites available
- ** Many sites available if culture technology is adapted to local conditions
- * Few sites available

Species	Markets	Culture technology	Site availability
a) Commercial species			
SHELLFISH			
Mussels	***	***	**
Oysters	***	***	**
Clams	**	**	**
FISH			
Trout	***	***	*
Ornamental fish	***	**	***
Catfish	**	**	***
Mullet	**	**	***
Tilapia	*	**	***
Carp	*	***	***
AQUATIC PLANTS			
Waterblommetjies	**	**	***
Ornamental plants	***	**	***
REPTILES			
Crocodiles	***	**	***
b) Threshold species			
Abalone	***	**	***
Atlantic salmon	***	***	**
Prawns (marine)	***	***	*
Prawns (freshwater)	**	**	**
Marron	***	*	***
Brine shrimp	***	**	*
Spirulina	***	**	***
Gracilaria	***	**	*
Grass carp	*	**	***

Factors which, in the short to medium term, will play a significant role in the rate of aquaculture development are the economic climate which in turn will largely determine the availability of venture capital, the legislative environment, the extent of research support from the state and the industry and the availability of suitably trained manpower. To marshal the desired support to overcome the aforementioned constraints, it is essential that the industry itself becomes more organised and unified. As mentioned elsewhere in this report the ideal vehicle through which to achieve this goal is the newly established "Aquaculture Association of South Africa".

Globally, state funded aquaculture teaching and research programmes have been the driving force behind the development of viable aquaculture technologies (eg. inter alia Taiwan, Israel, U.S.A., Japan, Norway, Scotland). As pointed out in Chapter 2 dedicated aquaculture research and teaching in South Africa is of recent origin, 1980 and 1982 respectively. The establishment of the FRD's National Aquaculture Programme, in 1984, provided a welcome boost to the research momentum, and as mentioned elsewhere, stimulated the aquaculture industry through the development and dissemination of aquaculture technology and the provision of skilled manpower.

While the growth and momentum of the industry in the recent past is indeed encouraging several producers have also expressed their concern about it. Some early warning lights have already begun to flicker. First and foremost amongst these is the critical shortage of skilled manpower as well as an inadequate research foundation. We are of the opinion that the budding industry would be jeopardized if these problems are not addressed in an appropriate and dynamic manner in the near future.

Apart from the obvious economic benefits such as the provision of edible and ornamental market commodities and job opportunities, the aquaculture industry also provides the opportunity for improved utilization of our national water resources and in several instances would reduce fishing pressure on natural stocks. It also has major implications for industrial and municipal effluent purification and, last but by no means least, provides the means for ensuring the survival of endangered species. We are of the opinion that the long term socio-economic benefits of aquaculture to the South African society will be significant. However, in order for the industry to reach its full potential it requires dedicated central support in terms of research and development. Considering the present state of the industry the scenario of a reduction in the research momentum could be likened to the exploitation of capital rather than interest.

The development momentum is also dependent on entrepreneurial spirit. According to several producers this is presently hampered significantly by disabling policies and legislation, particularly in terms of the availability of mariculture sites. Disabling legislation and state bureaucracy was in fact identified, during this survey, as one of the major stumbling blocks in the development of all branches of aquaculture. It is necessary therefore that the state, as well as the provincial authorities, develop policies and guidelines as regards the suitability and availability of sites, in order to serve the aquaculture community in an efficient manner.

A further constraint is the hesitancy by financial institutions to finance aquaculture projects, largely because they do not possess sufficient information regarding the viability of such ventures and tend to undervalue aquaculture assets. It is hoped that this document will aid financiers in reaching decisions.

The fact that the industry does not have a "governmental home" was seen by some producers to be another major stumbling block, despite being recently recognised by the Department of Agriculture as a legitimate farming enterprise. We are of the opinion that the newly formed Aquaculture Association of South Africa, once constituted, would be the right body to seek such a home. We are further of the opinion that once this has been achieved that the present policy constraints would be ameliorated and solved.

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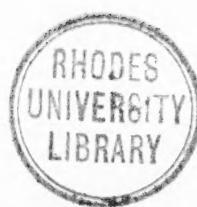
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AQUACULTURE IN SOUTH AFRICA; HISTORY, STATUS AND PROSPECTS documents the rapid growth of aquaculture in South Africa during the eighties. It is based on a CSIR / FRD funded survey of the industry conducted in 1988. The document provides a comprehensive overview which includes production statistics and development prospects for both existing and potential aquaculture species. It thus forms a benchmark by which to gauge the progress of aquaculture in South Africa facilitating more informed decision making and investment by those associated with the emerging industry. The publication marks the establishment of the Aquaculture Association of South Africa, a unified body which was formed to promote the interests of aquaculture in South Africa.

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